PROPOSED

ISO TC184/SC4 Standing Document

Technical Committee 184 for Industrial Automation Systems and Integration

Subcommittee 4 for Industrial Data

SC4 Industrial Data Framework

Chris Vaughan
Rolls-Royce plc, PO Box 31,
Derby, DE24 8BJ, United Kingdom
chris_vaughan@bigfoot.com

Yoshiaki Ishikawa
Ishikawajima-Harima Heavy Industries
Co. Ltd, 1-1, Toyosu 2-Chome
Koto-Ku, Tokyo 135-8731 Japan,
yoshiaki_ishikawa@ihi.co.jp

Table of Contents

List of Figures

List of Tables

Foreword

The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75% of the member bodies casting a vote.

This standing document was prepared by Technical Committee ISO/TC 184, *Industrial automation systems and integration*, Subcommittee SC4, *Industrial data*.

TC184/SC4 currently develops five standards

- STEP (ISO 10303 - Industrial automation systems and integration - Product data representation and exchange)

  ISO 10303 is an International Standard for the computer-interpretable representation and exchange of product data. The objective is to provide a neutral mechanism capable of describing product data throughout the life cycle of a product, independent from any particular system. The nature of this description makes it suitable not only for neutral file exchange, but also as a basis for implementing and sharing product databases and archiving.

  This International Standard is organised as a series of parts, each published separately. The parts of ISO 10303 fall into one of the following series: description methods, integrated resources, application interpreted constructs, application protocols, application modules, abstract test suites, implementation methods, and conformance testing. The series are described in ISO 10303-1.

- PLIB (ISO 13584 - Parts Library)

  ISO 13584 is a series of International Standards for the computer-sensible representation and exchange of part library data. The objective is to provide a mechanism capable of transferring parts library data, independent of any application, which is using a parts library data system. The nature of this description makes it suitable not only for the exchange of files containing parts, but also as a basis for implementing and sharing databases of parts library data.

- MANDATE (ISO 15531 - Industrial manufacturing management data)

  MANDATE covers industrial manufacturing management data, which is exchanged inside industrial manufacturing plants. Its scope covers the three areas of data exchanged between an industrial manufacturing company and its environment of manufacturing management activities; data able to reside in an industrial manufacturing company's resources database; data controlling and monitoring the flow of materials within an industrial manufacturing company.

- OIL & GAS (ISO 15926 - Industrial automation systems and integration)

  The purpose of this International Standard is to facilitate integration of data to support the life-cycle activities and processes of oil and gas production facilities.

- IIDEAS (ISO 18876 - Integration of industrial data for exchange access and sharing)

  ISO 18876 is designed to satisfy the following high level requirements:

  1. sharing and integration of data from multiple, heterogeneous sources;
  2. interoperability between applications and organizations that implement different standards.

A complete list of the parts of these standards is available from the Internet: http://www.nist.gov/sc4/

Introduction

The purpose of this standing document is to provide a high level framework within which SC4 standards can be developed, improving the consistency and interoperability of the standards.

This version of the document covers ISO 10303 but it is envisaged that future versions will extend the scope to the other SC4 standards.

The contents of this document are based on the premise that: -
- There are fundamental commonalities between different industries
- Industrial data can be considered as a product of some industrial process and therefore is subject to generalised Life Cycle Activities

This document does not define how the Framework will be used to direct the modularization of ISO 10303. A document "Recommended Practices when using the STEP Modular Approach" covers this area, it can be found on http://wg10step.aticorp.org.

This document contains the following major sections -
- Industrial Reference Models
- Usage Scenarios
- STEP Data Concepts
- STEP Frameworks

Industrial Reference Models

These are informative models, which describe the industrial environment within which SC4 standards are appropriate and show the commonality between the types of information in the environment. Two examples are the **Industry Structure** model, which describes the hierarchical structure of the customer supply chain, and the **Life Cycle Activities (LCA)** model, which defines a generalised set of Life Cycle Activities.
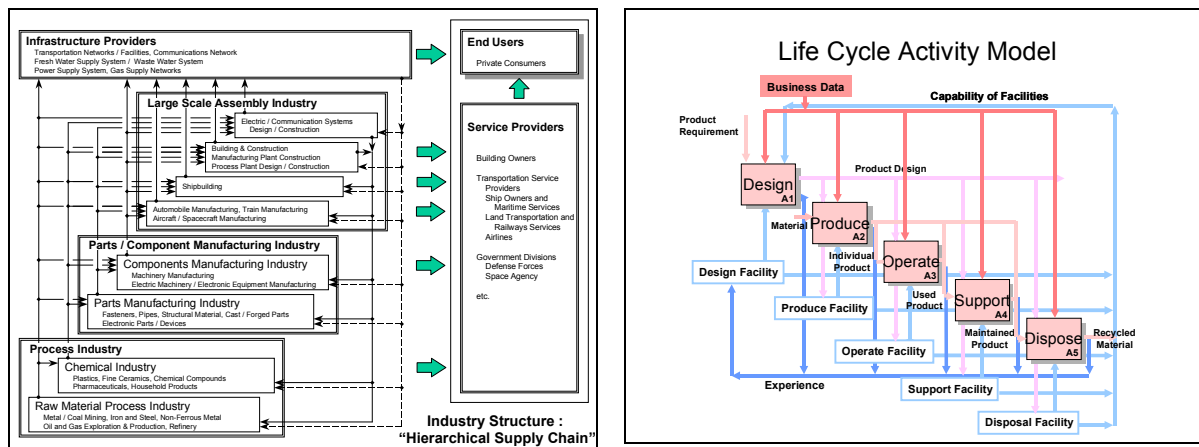
The LCA is defined at a level that demonstrates the common information flows through the lifecycle for the majority of manufactured products and enables mappings to other process models or terminology.

The LCA identifies that there are **four** distinct information flows

- Business Data
- Product Requirements
- Product Design
- Individual Product

A fundamental premise of the model is that all information flows in the LCA are of one of these types.

The LCA also provides a starting point for STEP Application Protocol (AP) development when defining the scope of an AP and the development of an Application Activity Model (AAM).

Usage Scenarios

This section describes the basic usage of the standards (data exchange, sharing, access and archiving).

STEP Data Concepts

This section describes the major STEP data concepts and relationships supported by STEP. A **Product Data Backbone** of basic concepts is described that would use these concepts and support the information flows in the Life Cycle Activity model. It also outlines the areas where an AP developer will most likely extend the backbone.

It is anticipated that formal data models covering this scope will be incorporated into Application Modules, possibly supported by extensions to the Common Resources.

The adoption of Application Modules (AMs) allows a set of core concepts to be defined once and interpreted once. This may also involve the expansion of the Common Resource (CR) models. Other AMs can then make use of these concepts without the need for the concept to be re-interpreted. Application Protocols developed using these AMs will then be interoperable, provided they conform to certain guidelines or rules. A more detailed description of modularization is contained in reference 22, "Overview description of STEP Modularization - to be published" and hence if used in Application Protocols would provide a minimum level of interoperability.

The implementation of this backbone will provide a basic but important degree of interoperability between Application Protocols. It is believed that adherence to the framework and backbone will aid the integration, inter-operability, and completeness of STEP/SC4 standards.

STEP Frameworks

These provide methods of categorising Application Protocols, Application Modules, and Common Resources and methods for finding overlaps and missing areas of the standards

The categorisation methods could be used in a STEP catalogue of APs and AMs to provide users methods of navigating the catalogue.

1 Scope

This chapter describes what is in scope of this document and what is out of scope.

1.1 In Scope

The following are within the scope of this document: -

1. **Industrial Reference Models**

These describe the context within which SC4 standards will be used and cover a number of aspects including the industrial structure, professional disciplines, life cycle activities and business function interaction and their decomposition. The reference models are aimed at being applicable to the vast majority of industrial sectors.

All life cycle activities are within scope:

- Design, Produce, Operate, Support, and Dispose

Production Control and the Configuration Management of a product are within scope.

In addition to these industries and their products, the facilities that create the products can themselves be considered products and are therefore also within scope: -

The interaction between the life cycle of a product and the running or operation of a company as a business is within scope. This includes the information flows between project management, configuration management, production control and product life cycle activities.

2. **Standards Usage Scenarios**

The description of the various ways industry may use the standards is in scope. For example, the terms data exchange, sharing, access, and archive are described and examples of their industrial use given.

3. **STEP Data Concepts**

The STEP data concepts section covers those concepts that should be common to all industrial sectors and that are within the scope of SC4 standards. In particular, this includes the following concepts: -

- Product
- Product Identification
- Product Versioning
- Product Definitions
- Product Properties
- States
- Representations
- Presentations

4. **STEP Framework**

The STEP framework sections cover the definition of various methods to categorise the various parts of STEP, which may be used in any catalogue of STEP/SC4 parts such as a AP or AM Catalogue.

5. **Standards**

All SC4 standards are within scope of this document. However, it is recognised that the majority of this version of the document is only applicable to STEP, ISO 10303. Future versions of this document may expand the scope to encompass all SC4 standards.

1.2 Out of Scope

The following are outside the scope of this document: -

1.   Service Industries

The reference models do not consider service industries. For instance, financial or banking services are not included.

2.   Standardisation of Industry

The standardisation of any industrial framework, structure, life cycle activities are out of scope, as is the standardisation of any technical terms for industry or professional disciplines.

3.   Business Functions

The concepts or standards concerned with the operation of a business organisation are out of the scope of this document. For instance, the business functions of Project Management and Procurement are out of scope. However, as stated above, the interface with these is within scope.

4.   Standards Development

Any architecture or definition of how STEP/SC4 standards support the industrial requirement is out of scope. In particular, any directives or process for STEP/SC4 standards development, such as AP development guidelines or AM Development guideline, are out of scope.

The scope or content of any existing or planned standard is out of scope.

2 Normative References

The following standards contain provisions which, through reference in this text, constitute provisions within this standing document. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standing document are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of the IEC and ISO maintain registers of currently valid International Standards.

ISO 10303-1:1994, *Industrial automation systems and integration - Product data representation and exchange - Part 1: Overview and fundamental principles*

ISO 10303-11:1994, *Industrial automation systems and integration - Product data representation and exchange - Part 11: Description methods: The EXPRESS language reference manual.*

3 Definitions and abbreviations

3.1 Terms defined in ISO 10303-1

application: a group of one or more processes creating or using product data.

application activity model (AAM): a model that describes an application in terms of its processes and information flows.

application protocol (AP): a part of this International Standard that specifies an application interpreted model satisfying the scope and information requirements for a specific application.

application reference model (ARM): an information model that describes the information requirements and constraints of a specific application context.

assembly: a product that is decomposable into a set of components or other assemblies from the perspective of a specific application.

component: a product that is not subject to decomposition from the perspective of a specific application.

data: a representation of information in a formal manner suitable for communication, interpretation, or processing by human beings or computers.

data exchange: the storing, accessing, transferring and archiving of data.

information: facts, concepts, or instructions.

information model: a formal model of a bounded set of facts, concepts, or instructions to meet a specified requirement.

integrated resources: a part of this International Standard that defines a group of resource constructs used as a basis for product data.

product: a thing or substance produced by a natural or artificial process.

product data: a representation of information about a product in a formal manner suitable for communication, interpretation, or processing by human beings or computers.

product information model: an information model which provides an abstract description of facts, concepts, and instructions about a product.

structure: a set of interrelated parts of a complex thing, and the relationships between them.

resource construct: a collection of EXPRESS language entities, types, functions, rules, and references that together define a valid description of an aspect of product data.

3.2 Other definitions

activity: action, process, transformation of a thing during a period of time

application module (AM): a reusable collection of a scope statement, information requirements, mappings and a module interpreted model that supports specific usage of product data across multiple application contexts.

behaviour: the collection of related properties and their description that show how a product interacts with its environment. For instance the thermal behaviour of a product.

catalogue: see **module catalogue**

directed acyclic graph (DAG): a collection of nodes and directed links such that no node is an ancestor (or descendant) of itself.

event: an incident that causes or starts a thing to move from one state to another.

EXPRESS: a formal data specification language, specified in ISO 10303-11, that provides the mechanism for the normative description of product data within integrated resources, application modules, and application protocols.

EXPRESS-G: the graphical representation of EXPRESS as defined in annex D of ISO 10303-11.

facility: the means or equipment enabling the performance of an action.

IDEF0: an activity modelling notation used to define application activity models within application protocols.

industry: the category describing a company's primary business activity. This category is usually determined by the largest portion of revenue. © Copyright The Washington Post

industrial data framework: a definition of how the various types of industrial data elements relate and may be categorised.

industrial reference model: a high-level description of the business requirements for data exchange and the industrial environment in which the SC4 standards will be used.

lifecycle activities: the set of tasks executed during the life of a product (the design, production, operation, support and disposal of a product).

mechanical part: a physical object that can be formed from material into a static shape.

MLIB: is the concept of a library for materials information. It would be a collection of dictionaries of Materials terminologies/vocabularies and their definitions as well as the properties of specific material types.

module catalogue: a set of summary descriptions of Application Modules (AMs) and Application Protocols (APs) and a mechanism (perhaps web based) that allows users to search for the module that meets their requirements. Data categories defined in a framework can be used within a catalogue to provide user-friendly methods of searching for the modules that are of interest.

presentation: the concepts necessary to create a presentation of information (often product information) through some form of sensory method. The sensory methods would include visual, tactile, auditory, and olfactory.

process: an activity that, is perceived to, adds value to *input*s and creates an *output*. Even the process of disposing of a product adds value by identifying which can be reused or recycled.

process model: a formal model that describes the activities that are performed to deliver a specified product.

product development programme: an organisation with a defined plan and resources with the specific objective of creating a new product.

product-in-focus: the product under consideration (PLCS), this is interchangeable with product

product type: a class of product distinguished by common essential characteristics; a kind, a sort.

professional discipline: a community of professional people possessing and applying a body of knowledge and skills applicable to a particular industrial specialism. Typically supported by some professional cross-industry organisation or institute.

property: characteristic, observable or measured aspect of a thing. Properties of a product are the concepts that characterise the product. E.g. shape, structure, thermal conductivity, the type of material the product is made from (material type).

12

representation: the act or instance of one thing standing as an equivalent of another thing. E.g. geometry can represent the shape of a product.

reusability (data reusability): the ability to use, add to and reuse specific product data repeatedly across or within different companies and or professional disciplines for agreed purposes.

state: condition, mode, aspect of a thing at an instant in time, represents the a situation or condition of a product during which certain physical laws, rules and policies apply.

supply chain: a term for the layers of processes involved in the design or manufacture of a product. These processes may be carried out within a single company or may be carried out by different companies. A company designing (or making) a product or a portion of a product may subcontract parts of the design (or manufacture) to companies within the supply chain.

3.3   Definition of terms in the Life Cycle Activities Reference Model

This section defines the terms used in the Life Cycle Activities Reference Model described in later sections.

3.3.1 Processes

A0	**Perform Product Life-Cycle**	the complete process of designing, manufacturing, operating, and supporting a product and also the final disposal of the product.
A1	**Design (the product)**	the activity in which a definition of the form, fit, and function of a product is created, analysed, tested and released.
A11	**Design Product**	the activity of producing a definition of the form, fit, and function for the whole product and decomposing this into requirements for the individual parts of the product.
A111	**Design and test product**	defining the physical and functional form of the design and validating this against some analytical or physical test.
A1111	**Design form of product**	defining the physical and functional form of the design
A1112	**Define Validation Tests**	defining the tests that are required to assure the product satisfies the requirements
A112	**Production Engineering**	evaluating a design for manufacture and defining how to produce.
A113	**Support Engineering**	evaluating a design for supportability and defining how it will be supported.
A114	**Disposal Engineering**	evaluating a design for final disposal and defining how it will be disposed.
A12	**Integrate Product**	the activity of synthesising the design definitions of parts of the product into a definition of the whole and the process of assessing the whole product's design against its requirements.
A2	**Produce (the product)**	the activity of manufacturing the product.
A21	**Plan Production**	the activity of planning the manufacturing activity and ordering the parts or materials to be used by the activity.
A22	**Produce Product**	the activity of turning the parts or material into the finished product and testing to see if it conforms to the product design.

A3	**Operate (the product)**	the activity of using the product for its intended purpose.
A4	**Support (the product)**	the activity of maintaining, modifying, and (or) repairing the product for further operation.
A5	**Dispose (of the product)**	the activity of destroying or recycling the product.

3.3.2 Business Objects in the LCA Reference Model

Business Data - the rules that control the Life Cycle Activities. Examples include: -

- The plan or time scales in which the process should be carried out.
- The laws or regulations that control how the work should be performed or how the product should be defined.
- The business approval to move from one stage to another.

Capabilities of Facility - the definition of what each facility is able to achieve, either an individual facility or a designed facility.

Experience - information about the operation of the Life Cycle Activities, (design, produce, operate, support, dispose), in relation to their operation on a particular product. This information can then be used to improve the processes for similar products. Examples: -

- Information about how the product is manufactured and how it could be changed to make it less costly to produce.
- Within the aerospace industry products such as aircraft engines often have their performance monitored. This can be used to predict maintenance issues. The individual performance of the product can be used in the design process to improve similar products.
- The support process may encounter problems when maintaining or repairing the product and this information would be passed back into the design process.

Facility - the means or equipment facilitating the performance of an action.

Individual Product - is a physical product that could be sold to a customer, considered to be an asset to a business. The Produce process creates the individual physical products. Information about the individual product will include many properties; for example, its shape, observed behaviour, date produced, serial number and the parts used in its construction.

Maintained Product - an individual product that has been repaired or modified to enable it to continue to operate.

Product Design - is a set of information that defines a product. It would typically contain information about

- the form, fit, and function of the product
- the predicted behaviour of the product
- the manufacture, operation, support, and disposal of the product.

The information can vary in quality and purpose. It includes

- all of the necessary information to fully define the product for manufacture, operation, support, and disposal
- an initial or concept design. A concept design would often be reviewed by a business prior to a full design being carried out, thus reducing the business risk.

Market / Customer Requirements - is the statement of the characteristics for a product type that the market or customer requires. It contains not only the characteristics of the product type but also business data, in terms of items such as acceptable purchase price, and delivery details.

Material - is a substance used as input to a production activity. Material then becomes a product when processes through the produce facility. It may be considered as input by succeeding processes. See section "6.2.5 Different Viewpoints" on page 54.

Recycled Material - an individual product or parts of a product that are available to be reworked for some other use. The disposal process will recycle any material from the product that is of any use. This material, in its turn, will be used in the production of other products.

Product Requirement - is the statement of the characteristics that an individual product should have and their relative importance. This is a set of the various characteristics of the product, e.g. its behaviour, shape and weight, but it does not contain items concerned with the business such as selling price or delivery details.

Used Product - the individual product as or after it has been operated for some time.

3.4   Abbreviations

AAM : Application Activity Model
AEC : Architecture, Engineering, Construction
AIC : Application Interpreted Construct
AIR : Application Integrated Resource
AP : Application Protocol
ARM : Application Reference Model
CC : Conformance Class
CR : Common Resource
IIM : Industrial Information Model
IR : Integrated Resource
GIR : Generic Integrated Resource
GUoF : Generalised Unit of Functionality
NWI : New Work Item
LCA : Life Cycle Activities
PWI : Preliminary Work Item
SID : SC4 Industrial Data
STEP : Standard for the Exchange of Product data model
UoF : Unit of Functionality

4   Industrial Reference Models

This chapter defines a number of informative Industrial Reference Models that describe the industrial environment within which SC4 standards are required. Three models are described.

Industrial Structure - which describes industry , the types of products and provides a high level classification of these.

Professional Disciplines - which describes the engineering disciplines that will create and use data and provides a foundation for understanding the speciality or commonality of products.

Life Cycle Activities - which describes the processes involved in creating and supporting a product. The Life Cycle Activities reference model shows the similarities between the various information flows. It defines four types of information flow that need to be supported.

4.1   Industrial Structure

The following diagram illustrates the types of product and industries that the STEP and SC4 standards are required to support.

It illustrates the supply chain in terms of the types of product that are produced and the uses to which those products are put. Raw Material Process Industries are identified at the bottom level in the hierarchy and Infrastructure providers at the top level in the supply chain. Service Providers and End Users are at the top of the hierarchy.
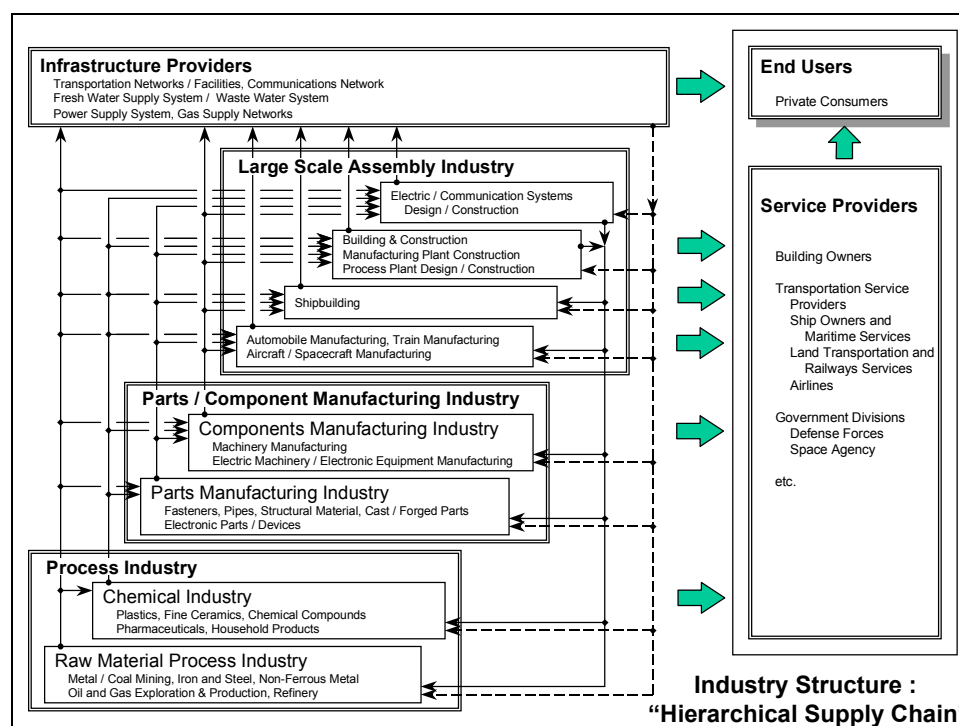

Figure 1 - Industrial Structure

The categories shown in the diagram above are not prescriptive, but they do give a high level overview of the industrial supply chain. This model can be used when validating the industrial applicability of the more general parts of the standard by reviewing each industry. A description of the categories is given below, together with examples.

Category	Description	Examples
Raw Material Process Industry	The manufacture or production of the basic materials used as a feedstock for a manufacturing process, often crude unprocessed or partially processed material.	• Chemical Suppliers • Metal Suppliers • Mineral Suppliers • Oil and Gas Suppliers • Food Industry
Chemical Industry	The manufacture of chemical products	• Pharmaceuticals, Household Products • Plastics, Ceramics, Chemical Compounds
Parts Manufacturing Industry	The manufacture of discrete items, used by multiple industry sectors.	• Fasteners Manufacturers (e.g. nuts, bolts) • Standard Parts Manufacturers (e.g. bearings, seals) • Electronic Parts and Devices Manufacturers
Component Manufacturing Industry	The manufacture of functional components, including simpler mechanical and electrical products, for use in larger assemblies or by end users.	• Mechanical Component Manufacturers (e.g. pumps, valves, gears) • Power Generation Engine Manufacturers (e.g. reciprocating engines, gas turbines) • Electric Machinery / Electronic Equipment Manufacturers • Instrumentation Manufacturers • White goods and Consumer Electronics Manufacturers
Large Scale Assembly Industry	The "manufacture" of vehicles, ships, process plant, electrical or other facilities that integrate multiple components within a single physical product or geographic site.	• Car, Truck, Bus & Railway Train Makers • Aircraft / Space Craft Manufacturers • Shipbuilders • Building & Construction Firms • Process Plant Builders/Suppliers • Power Generation Plants Builders/Suppliers
Infrastructures providers	The "manufacture" or construction of integrated infrastructure systems comprising multiple assemblies and components, across multiple sites or locations, that provides the infrastructure for a civilisation.	• Waters Supply and Sewage Systems • Transportation Networks / Facilities • Communications Networks • Power Supply Systems • Gas Supply Networks
Service providers	The operators and users of the manufactured products or infrastructures.	• Building Owners • Land Transportation Providers (e,g, Railway Services) • Ship Owners/Maritime Service Providers • Plant Owners • Airlines • Defence Forces • Space Agency • Private Consumers

4.1.1 Use of Product Data within Industry

The previous figure illustrates many of the major flows of information within industry as a whole. SC4 standards are aimed at providing the standards to enable these flows. For standards to be successful, product data must be reusable as it is passed between partners, used, updated, and passed on again.

The following assumptions are made about the industrial environment in which these standards will be used:

1. Each company and professional discipline (part of a company) use Product Data engineering processes, technology, and terminology of their own choice.

2. Collaborations or partnerships between companies and or professional disciplines are on an "Equal Partnership" principle. Regardless of position in the supply chain, an industrial company can acquire the product data it needs in the form that it needs it i.e. conforming to the standard mandated in the respective exchange agreement.

3. Exchange of industrial information in collaborations or partnerships between companies or professional disciplines are facilitated by agreements which mandate

   • The standards (APs) that will be used to exchange product data and the use of those standards.

   • The processes and technology that will be used to create and use product data.

   • The quality of the product data that will be created.

4. Product Data is created fit for purpose.

4.2 Professional Discipline

The characteristics or properties of a given product (or product type) are typically described in the context of an industry and some professional discipline.

For the purposes of this document a *Professional Discipline is defined as*

A community of professional people possessing and applying a body of knowledge and skills applicable to a particular industrial specialism. Typically supported by some professional cross-industry organisation or institute.

The relationships with Industry and Product Type are illustrated in the following diagram.
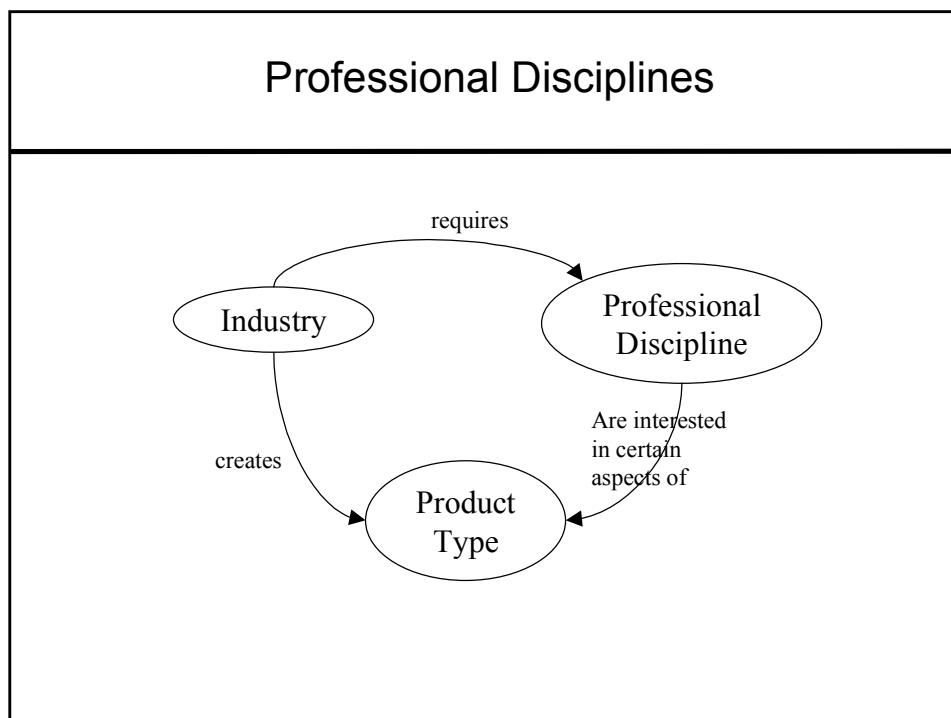

Figure 2 - Relationship between Professional Discipline, Industry and Product Type

4.2.1 An Analysis of Professional Disciplines

"Table 7 - Examples of Professional Disciplines", page 90, provides a list of examples of the more common Professional Disciplines that can be found within industry.

An analysis of these Professional Disciplines against the industries that use them allows us to understand both the uniqueness and commonality of products.

The uniqueness of a product is dependent on:

- The characteristics of the product and the technologies and sciences applied by its principal discipline.
- The history of the product and its principal discipline, which often sets the terminology used in that industry.

The commonalities of products depends on:

- The sciences and technologies commonly applied by principal and supporting disciplines across product types.

"Table 1 - Professional Discipline versus Industry (or Product)", page 81, presents an analysis of professional disciplines used within industry. In this table the relationships between professional discipline and industry and/or product are show as either **P** for main product of the discipline or **W** for a discipline working for that industry

The most important message to be shown by this analysis is that, **most disciplines are used across many industries and there is a large degree of commonality between industries**.

4.3 Life Cycle Activities

The following diagram provides an overview of the types of activity that is involved when producing a new product and managing it through its complete life cycle, from cradle to grave. The activities inside a double line box are those in scope of this document and those within a single line are out of scope.
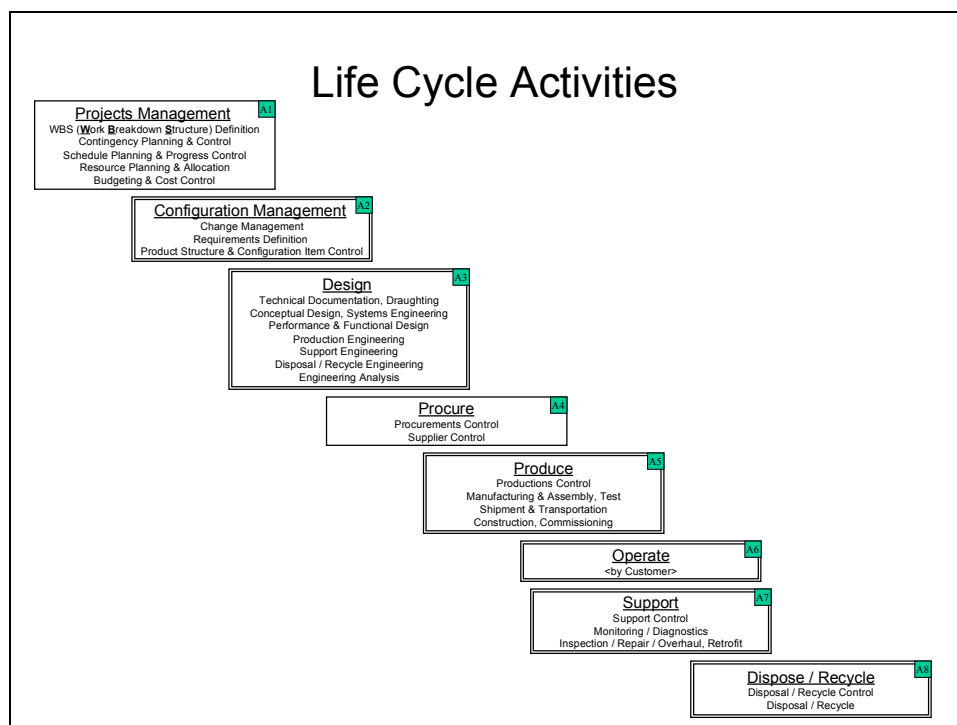

Figure 3 - Life Cycle Activities

To understand the scope of these activities we can look at an informal decomposition of the processes contained in "Table 5 - Decomposition of Life Cycle Activities", page 87.

The following sections define more formal IDEF0 definitions of these activities. A brief description of the IDEF0 notation is provided in Annex C - IDEF0 - Process Modelling, page 94. The major portion of the formal model is the Life Cycle Activities Reference Model. This provides an understanding of the activities involved in the Life Cycle of a Product and how they relate to each other. Several of the types or categories of information that need to be supported can be seen from this model. In addition, the model provides a starting point for more detailed activity models to be developed such as the AAM models created as part of an Application Protocol.

4.3.1 Levels of Business Process

The processes necessary to create a product and to operate a business that manages those processes can be categorised into a number of levels.

Business

The activities necessary for the operation of a business as either a profit or non-profit making organisation. These activities include processes such as: -

- Define Policies
- Define Roles and Relationships
- Business Planning
- Asset Management
- Sales / Order Release
- Supply Chain Management
- Product Assessment
- Life Cycle Configuration Management
- Requirements Definition
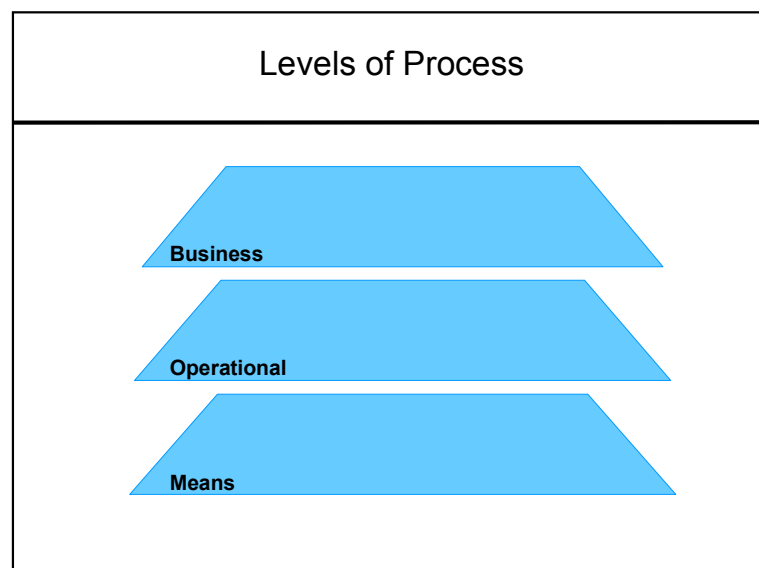- Configuration Item Control
- Change Management

Figure 4 - Levels of Process

Operational

The activities to design, produce, support and dispose of a product throughout its complete life cycle

Means

The activities to create and support the facilities (or means) required to carry out the operational level activities.
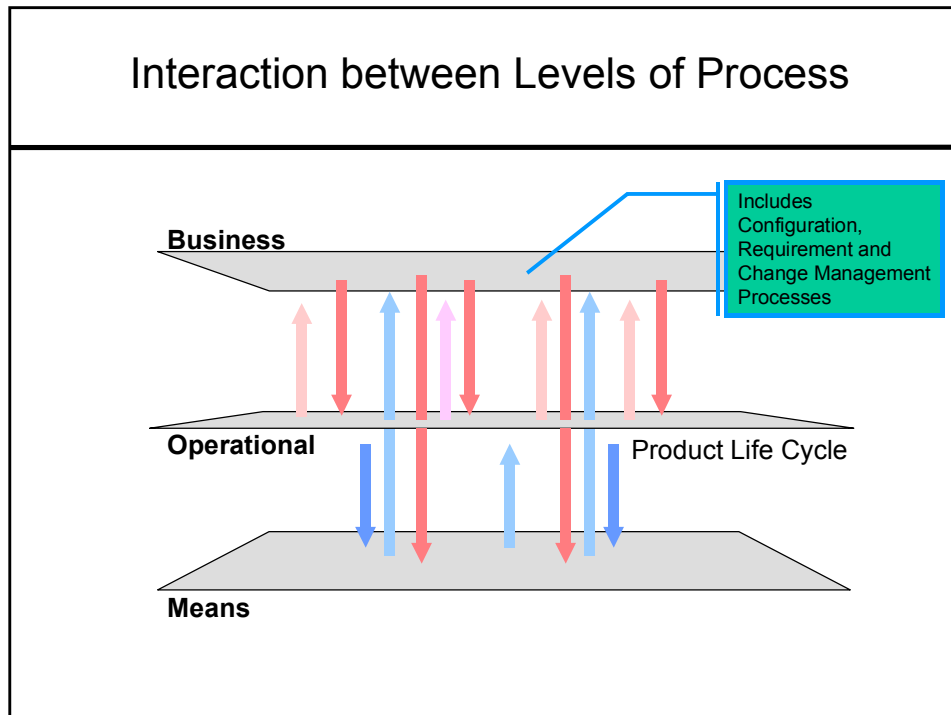
Figure 5 - Interaction between Levels of Process

These three levels of process interact with each other.

- Data from the **Operational** and **Means** layers is generally available to the **Business** layer, which monitors the operation of these layers.

- The **Business** layer provides *control* flows to the other layers, in the form of approval and change management.

- The **Means** layer provides the facilities and knowledge of how to carry out the **Operational** processes.

- The **Operational** layer processes gain experience about the operation of the various processes and this is provided to the **Means** layer for use in future designs.

SC4 Standards are mainly aimed at the operational and means layers, but they will also cover the configuration control, change control, and requirement definition areas.

4.3.1.1 Interaction of Business and Operation Levels

The following diagram shows a more detailed view of how the Business and Operation levels may interact.

- The Project Management activity provides **control** on the process in the Operation level, which in turn provides feedback when the process completes.

- The business level process reviews the deliverables and **approves** or **rejects** them from an overall commercial viewpoint.

- Rejection and the subsequent rework create new **versions** of the product or its variants.

Through this control of the operation, change management of the product is maintained.

Figure 6 - Interaction between Business and Operational Levels

4.3.1.2 Change/Configuration Management

The following diagram describes, in the IDEF0 notation, the interaction processes on the business layer with the Life Cycle Activities on the operational layer.

Figure 7 - Interaction between Levels - IDEF0

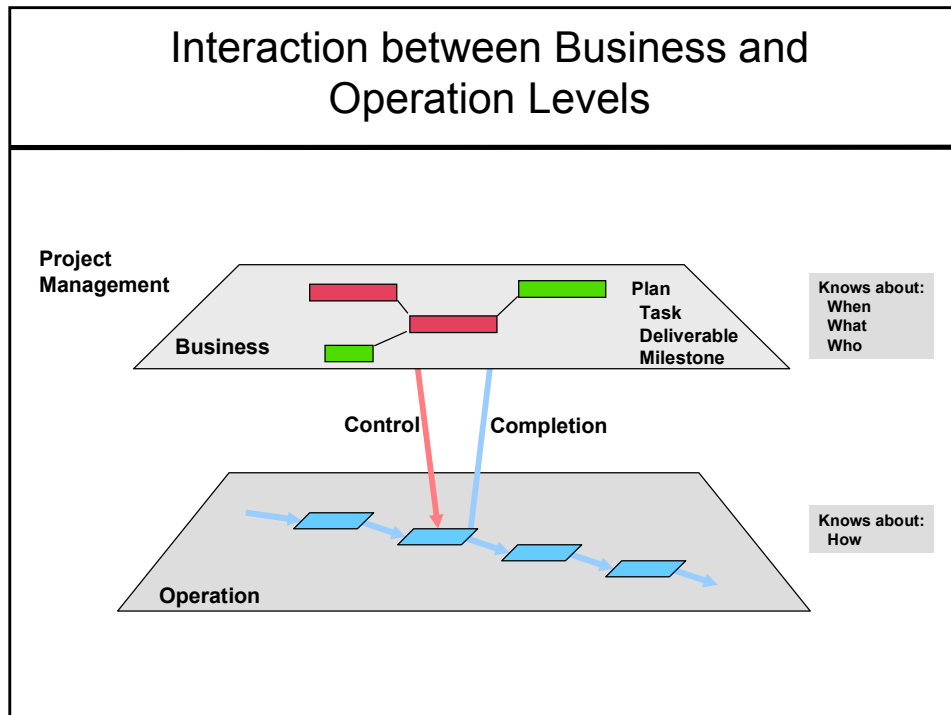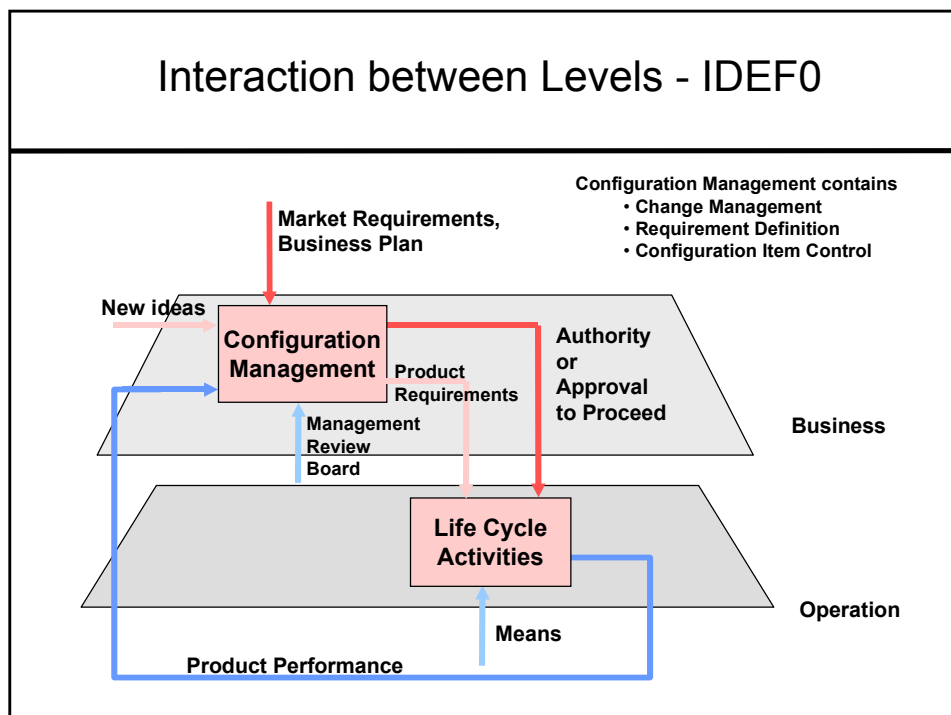In a later section, it is shown that the Life Cycle Activities model applies both to the operational and means layers. Hence, this diagram also covers the interaction between the business and means layers.

The process at the business level that controls the Life Cycle Activities is **Configuration Management**. This is defined as containing **Change Management, Requirement Definition,** and **Configuration Item Contro**l.

Configuration Management takes new ideas and experience and produces a statement of the requirements that the product should satisfy (**Product Requirements**). It does this in line with the **Market Requirements** and the **Business Plan** for the organisation. It also monitors the Life Cycle Activities and then issues an **Authority or approval to proceed** at the appropriate times. The **Product Performance** feeds information back to the business level about the viability of the product during all stages of the Life Cycle Activities.

4.3.2 Life Cycle Activities (LCA) Reference Model

This section defines basic operational processes that SC4 standards support. This describes the activities involved in the production of most industrial products. It shows what activities are performed but not how or who performs them. These processes belong on the operational layer but it will also be shown that they also apply to the means layer.

- The **purpose** of the LCA reference model is to provide a process model that **highlights the commonality** of the data or information flows.

- In a later section, a single data framework or backbone is described that is intended to support all of these types of information.

- The backbone can then be used and extended by Application Protocols to support the industrial requirement in a way that ensures interoperability.

The LCA is not intended to be a definitive process model that details, to a low level, the complete process description. The terminology used may not fit with all industries but it should be possible for other process models and terminology to be mapped to this reference model.

4.3.2.1 Description of the Life Cycle Activities Reference model

This diagram shows the first level of the Life Cycle Activities model. Later sections show the rationale for this model and also provide further levels of detail. For the reader to fully understand the LCA; it is important that they study this rationale and, in particular, the principles that have been used in the modelling. See section "Principles used in Defining the Process Model", page 29.
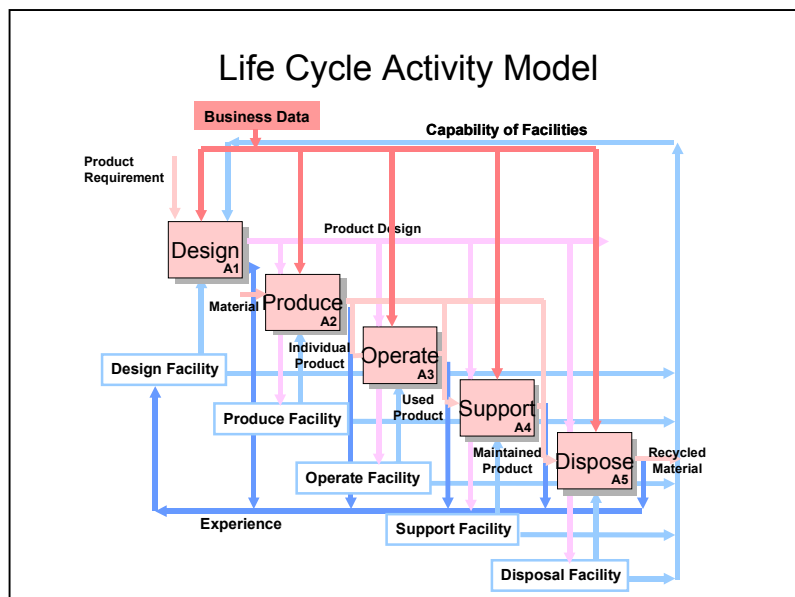

Figure 8 - Life Cycle Activities Reference Model

The complete model shows: -

- The life cycle processes: **Design, Produce, Operate, Support, Dispose**.

  These processes define WHAT is done, not HOW or by WHOM. For instance, a manufacturer may change a design, in which case they are considered to be carrying out the **design** process.

- The **Product Requirement** is *a control* on the Design process. This process produces a design or definition of the product.

- The Produce, Operate, Support and Dispose processes have **Individual Product** instances as both *input* and an *output*.

- The **Product Design** is a *control* on the rest of the Life Cycle Activities.

- The *means* for the processes follow the same Life Cycle Activities and can be supported by the same data model. A **Facility** is an **Individual Product**.

- The **Product Design** can also be a *control* on the Life Cycle Activities of the Facilities.

- The design of a product will take into consideration the past experience in making, operating, supporting, or disposing of similar products. **Experience** is fed back into the Design Facility and is used to improve the next occurrence of the Design activity.

- A Product must be designed in such a way that allows it to be manufactured, operated, and supported. The Design process is *controlled* by the **Capabilities** of the Operator and the Produce and Support Facilities. For some industries, this would also include the Disposal facility.

    - For some industries, new facilities may be required to produce or support a new Product and the Produce and Support Facilities may be designed and created in parallel to the Product. In these cases, the design of the Product would be *controlled* not by the actual capabilities of those facilities but by the capabilities defined in the design of the facility.

4.3.2.2 Information Flows

The LCA shows many of the types or categories of information that need to be supported within SC4 standards. It shows or will show later that the product data moving through the process is of three major types **Product Requirement**, **Product Design**, **Individual Product**

- The **Product Requirement** defines the characteristics needed of the final delivered product.

- The **Product Design** includes information defined during the Design stages that *control* how the Produce, Operate, Support and Dispose processes should be conducted.

- The **Individual Product** includes information about history or operation of a particular product instance during the Design, Produce, Operate, Support and Dispose processes.

- The **Capability of Facilities** is a statement about the facility, either as a designed one or as an individual one, and can be supported by the **same** data model (**Product Design** or **Individual Product).**

- The **Experience** information flow is information about the operation of the individual processes and how it relates to the product being created. The operation of these processes is the operation of the actual or individual product or facilities. Since the facilities are Products in there own right, **Experience** can also be supported by the **same** data model.**(Individual Product)**

4.3.2.3 Context Diagram
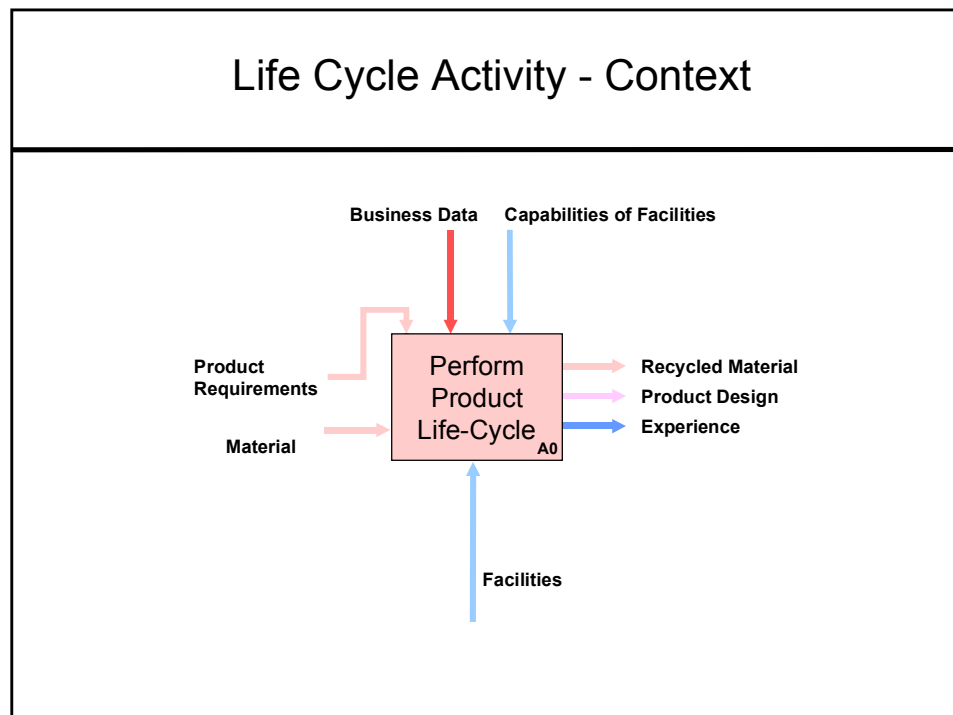
Figure 9 - Life Cycle Activity - Context

This diagram shows the IDEF0 context level for the **Life Cycle Activities**. It shows that: -

- the Product Requirements, Business Data and the Facility Capability control the process
- Material is the input to the process
- the Facilities being the means enabling the operation of the process
- the outputs of the process are the Product Design, Recycled Material, and Experience.

4.3.3 Rationale for Life Cycle Activities Reference Model

This section describes the rationale behind the **Life Cycle Activities Reference Model**. Several of the types or categories of information that need to be supported can be seen from this model.

4.3.3.1 Product Life-Cycle Processes

This diagram illustrates the typical processes for creating a product. To complete this picture, the main inputs, outputs, means, and controls must be identified for each process.

Note that time is not shown on this diagram. However the processes are often carried out in the order shown with the operate and support processes carried out concurrently.
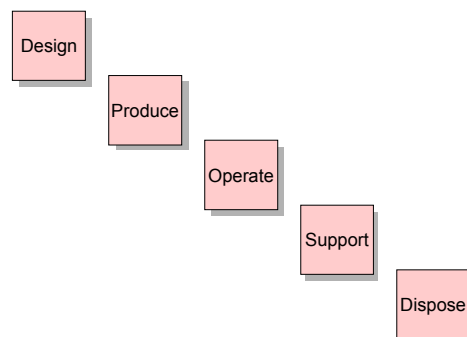
4.3.3.2 Primary Information Flows

The main "input" into these processes is the Product Requirements (from the customer) into the Design process. The Design process can only provide feedback to suggest changes to the requirements. Hence the requirements are a control on the Design activity rather than an input.

During the life cycle two main objects are generated: -

- The design of the product - the **product design** (The Design process could produce either a full product design or a concept design). The Product Design is a *control* on the Make, Operate, Support and Dispose processes. It is not an *input* to any of these processes since they are not allowed to change it. If the Product Design has to be changed while the product is being produced then it is equivalent to going back into Design and producing a new version.

- **Individual products** (instances of actual products) that are supposed to conform to the product design. (Types of Individual Product include Used Product, Maintained Product, and Recycled Material). Each of these processes add value to the **Individual Product** and hence they are shown as *inputs* and *outputs*.
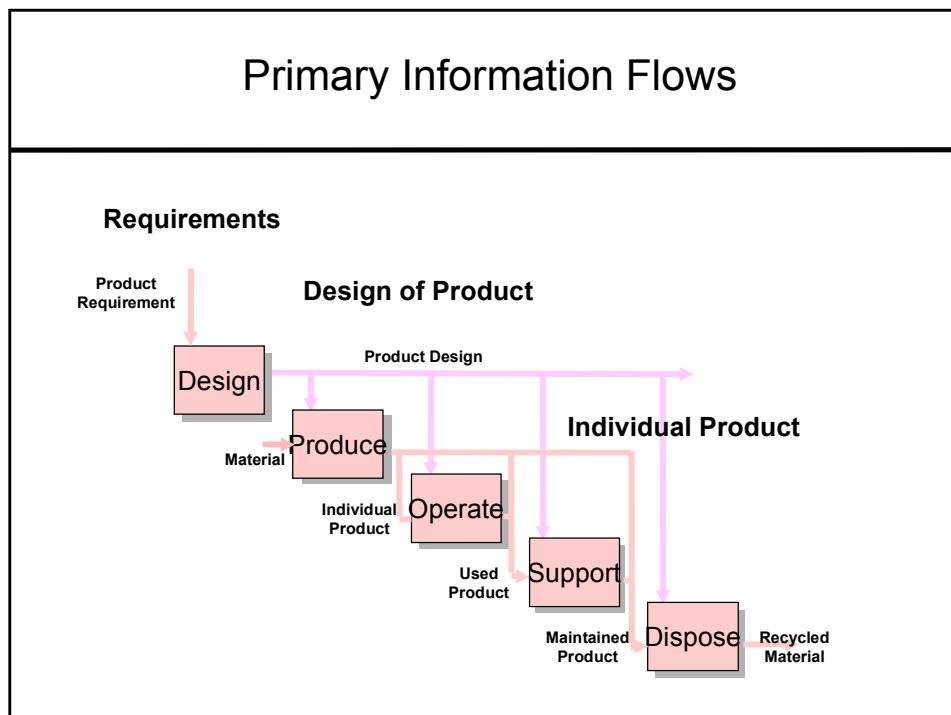
Figure 10 - LCA Primary Information Flows

4.3.3.3 Means

The next addition to the process descriptions is to add the '*means*' required to achieve each process in the life cycle.

The *means* for carrying out the Produce or manufacturing process is the set of facilities, people, tools etc. that collectively carry out that process. In this document, this group will be called the Produce Facility.

To carry out its function, the Produce Facility will have had to have been designed and built. While it is

manufacturing products, it will need to be maintained or supported. At the end of its useful life, it will be disposed of. Facilities therefore follow the same lifecycle as any other Product.

The next diagram illustrates how the lifecycle of the Produce Facility (or the '*Means*') relates to the life cycle of the Product.

It can be seen that the lifecycle processes of the Produce Facility are the same as for the Product,

- Design the Produce Facility,
- Produce the Produce Facility,
- Operate the Produce Facility
- Support the Produce Facility,
- Dispose of the Produce Facility.

The only difference is that the Product is now the Produce Facility.
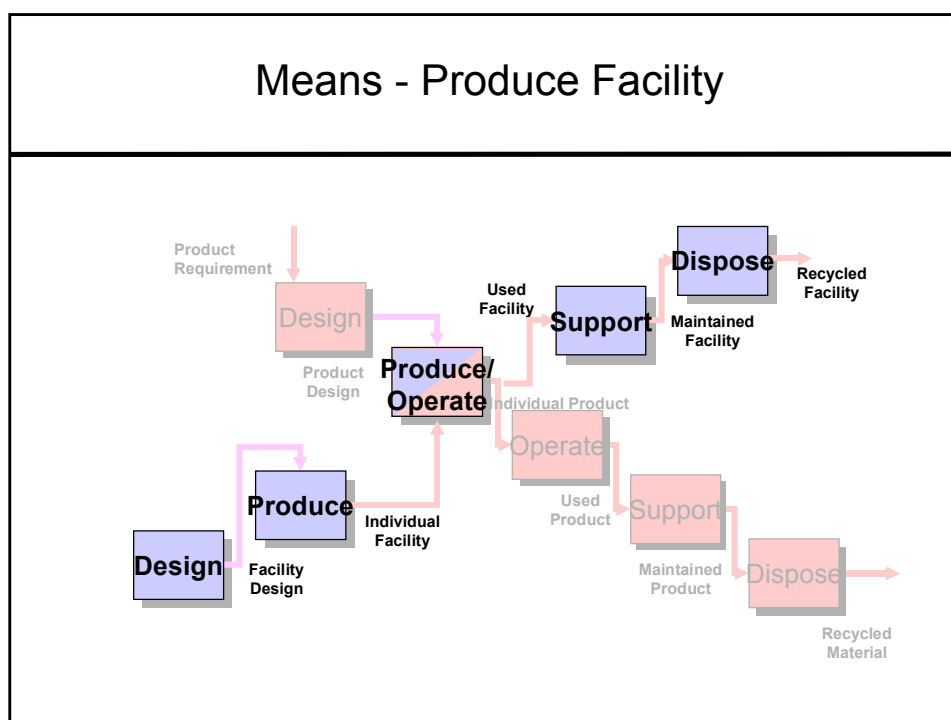
Figure 11 - Means - Produce Facility

Note that the 'Operate Produce Facility' process is the same as 'Produce the Product'.

The processes for creating the Design Facility, the Support Facility etc. follow the same structure.

This makes the life cycle of the Product: -

Design		Operate the Design Facility
Produce		Operate the Produce Facility
Operate	Is equivalent to	Operate the "Operate" Facility
Support		Operate the Support Facility
Dispose		Operate the Dispose Facility

4.3.3.4 Control of the Life Cycle Activities
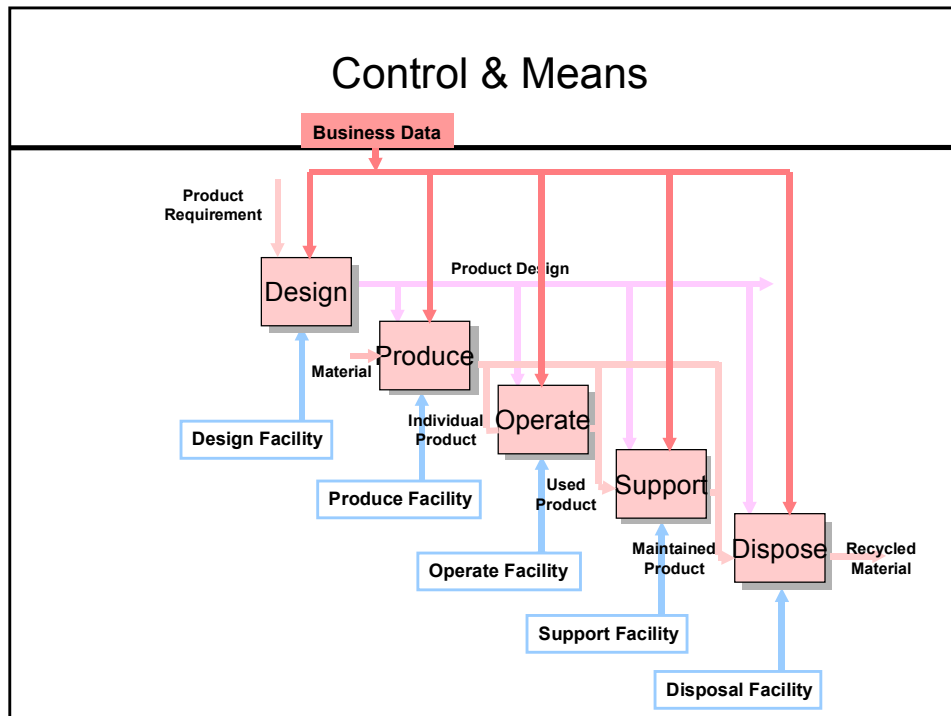
Figure 12 - Control and Means

To complete the basic process descriptions, the *control* of the processes must be added. Business management processes *control* the life cycle of the Product.

Building the ideas described so far into one illustration gives us the above diagram that describes the typical process for creating a product.

The diagram shows

- the **product requirement**

- the **product design**

- the **individual product**

- the *means* for creating the individual products and product design. e.g. the Design Facility, Produce Facility

- the **Business Data** controlling the process, this includes items such as the resource, schedule, approval, regulations

4.3.3.5 Life Cycle Activities Reference Model

The above diagram only shows the basic concepts and does not include any of the information flows that feedback information from the downstream processes (produce, operate, etc) back into the earlier processes.

Adding these feedback flows gives the complete **Life Cycle Activities Reference Model**.

Life Cycle Activity Model

Business Data

Capability of Facilities

Product
Requirement

Product Design

Design
A1

Produce
A2

Material

Operate
A3

Individual
Product

Design Facility

Used
Product

Support
A4

Produce Facility

Maintained
Product

Dispose
A5

Recycled
Material

Operate Facility

Support Facility

Experience

Disposal Facility
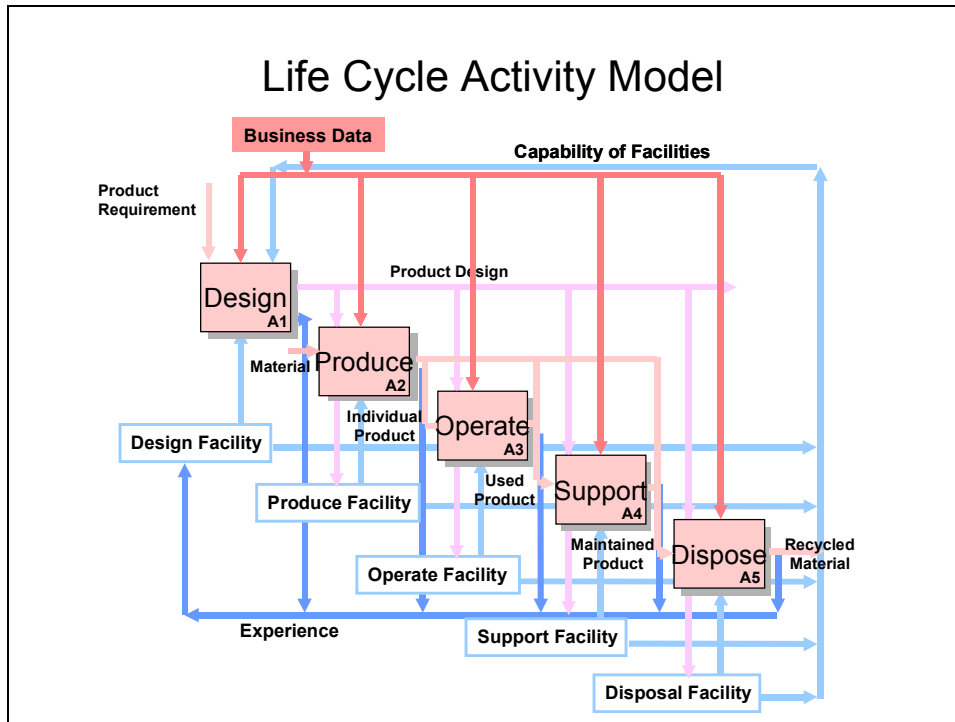
Figure 13 - Life Cycle Activity Reference Model

The design work will take into consideration past experience in producing, operating, supporting or disposing of similar products. This **Experience** is feedback from the later processes into the Design process via the Design Facility.

A Product must be designed in such a way that allows it to be manufactured, operated and supported. The Design process is therefore controlled by the **Capabilities** of the Operator and the Produce and Support Facilities. For some industries, this would also include the Disposal facility.

For some industries, new facilities may be required to produce or support a new Product and the Produce and Support Facilities may be designed and created in parallel to the Product. In these cases, the design of the Product would be controlled not by the actual capabilities of those facilities but by the capabilities defined in the design of the facility.

If a new Facility is created for a particular Product, (such as a new manufacturing plant is designed) then the Product Design is a *control* on the Facility's life cycle. This is discussed more in a later section.

4.3.3.6 Principles used in Defining the Process Model

A number of principles have been used in creating the LCA model. The principles are: -

- The only information shown as an *input* to a process is that information that is changed and has value added by the process. Information that is just used by a process, but not changed is shown as a *means* or as a *control*.

- The *outputs* from processes are the fundamental items created by it. These will normally be complex items that can be decomposed.

- Processes are only decomposed where the resultant model is generally true for all industrial products.

- The model tries to be neutral in that it does not to take any specific view (e.g. from a design, manufacturing or support perspective). It does, however, highlight the commonalities between the information flows.

- All the processes must adhere to the same overall scope or context. In the LCA model, this means that all the processes must be truly part of the product life cycle. They must apply to the same product as implied by the context diagram. Some models combine the facility processes with that of the end product. This paper defines them as following the same basic process. Hence activities such as training designers or support staff are not part of product life cycle but of the Facility life cycle. Both products are supported by the same process and data model. Similarly, the generation of Material Properties data is part of the Design Facility life cycle.

- The model is aimed at **what** processes are carried out. It is not concerned with **who** carries out the processes. The processes are not restricted to the scope of any particular **organisation**, it is understood that any one organisation is unlikely to carry out all of the processes. The *means* show what is required to carry out a process but not who owns the *means* or any other **organisational** aspect.

4.3.3.7 Interaction of Product Life Cycle with the Facility Life Cycle

In an earlier section, it was shown how the Facilities follow the same life cycle as a Product. The following diagram shows the interactions between the life cycle of the Product and that of the Produce Facility. It is a more detailed version of the diagram described in 'Means'.
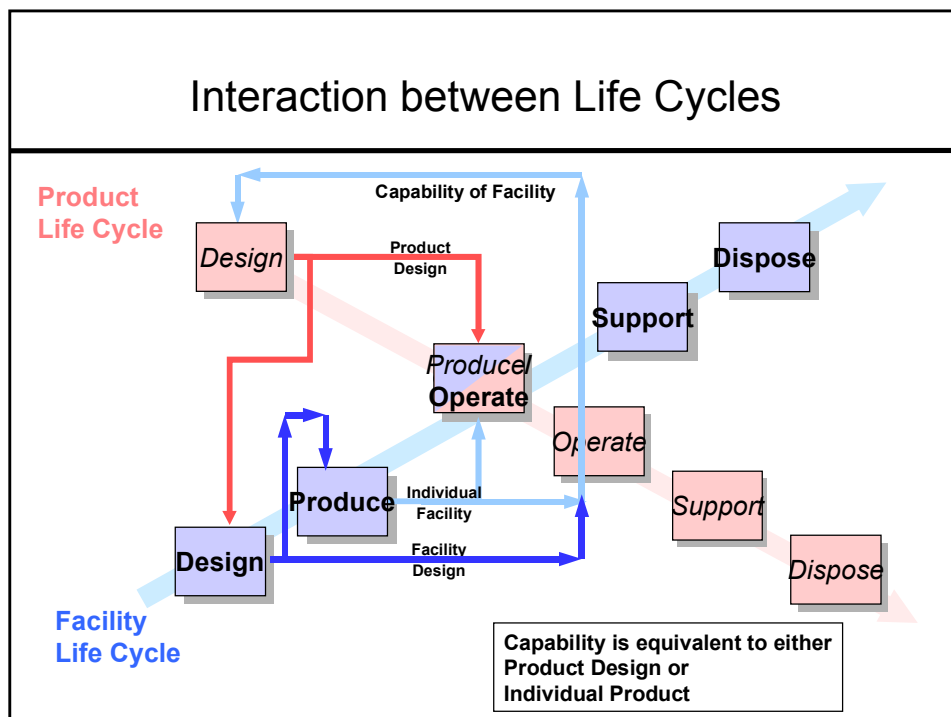
Figure 14 - Interaction between Life Cycles

The diagram shows that: -

- The individual Produce Facility is the *means* for the Produce Product process.

- The Product Design is a *control* to the Produce process but also can be a *control* on the Facility Design. **This enables the facility to be designed to manufacture certain products.**

- The Capability of the Produce Facility is a *control* on the Product Design process. This *control* can either be the capability of the individual facility or the intended facility (Facility Design). **This enables the product to be designed so that the facility can produce it.**

- The Capability of the Produce Facility is the capability of either a designed one or an actual (individual)

30

facility. This implies that an additional information model for Capability is not required as it can use the ones for Product Design or Individual Product.

Similar diagrams and conclusions can also be draw for the other Facilities; for instance, the Support Facility. The capability of the Support Facility is an important information flow within the Logistics world. The above implies that this flow should be supported by the same general information model as those used within the Life Cycle Activities.

4.3.4 Lower Levels of Process within the Life Cycle

This section decomposes some of the processes in the LCA model to a lower level of detail.

- Design Supply Chain
- Production Supply Chain
- Interaction with Sub Life Cycle Activities
- Decomposition of Design and Produce

4.3.4.1 Design Supply Chain

A term that is often used in conjunction with data exchange between companies is the supply chain.

There are at least two supply chains, the **design supply chain** and the **production supply chain**.

The following picture illustrates the design supply chain The picture shows the product decomposed into sub-products and then into components. The **number of levels** of decomposition depends on the **complexity of the product.** . When a company designs its products it will often sub-contract the design of sub-products or components to other companies.

The company will define the **requirements** to their sub-contractor and will receive back a definition of the design (sub-product design). These processes are, of course, true regardless of whether they are sub-contracted or not.

Note: The processes at the bottom (component) level are shown as irreducible. Since the component has not been decomposed, the 'Integration' process is not required.
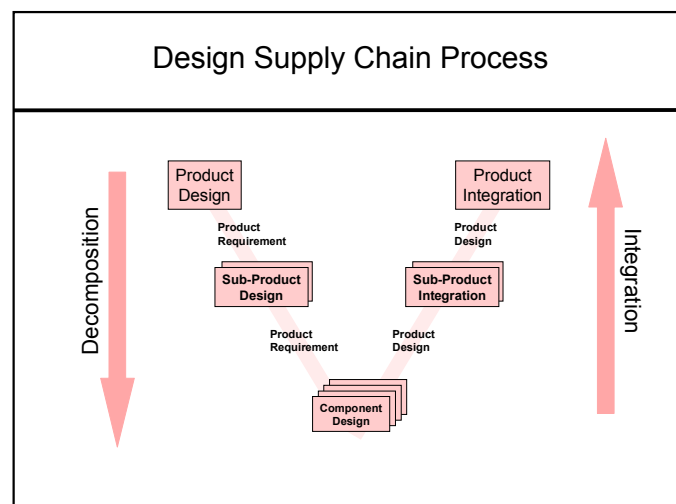
4.3.4.2 Production Supply Chain

The Production supply chain is similar to the design supply chain. The process is initiated by an Order, which is cascaded down the supply chain. As parts are manufactured from Material they are delivered up the supply chain where they are assembled and finally become the end product.

Design Supply Chain Process

Production Supply Chain Process
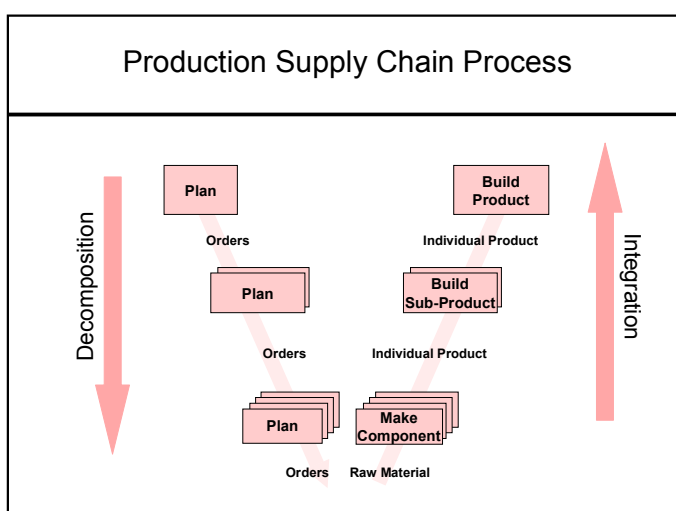
4.3.4.3 Interaction with Sub Product

At any level of the supply chains, the members of that level's organisations are responsible for a particular product, the **product-in-focus**. They generally view the sub product design as a single entity. The succeeding levels generate a next level decomposition of the sub product (their **product-in-focus**) and regards each of these lower items as single irreducible items in its operation.

It can be seen from both the Design and Production supply chain pictures that the processes at each level of the diagram are the same. They are the same process but are applied to different instances of different products (different **product-in-focus**).

The following diagram shows

- Some of the LCA processes replicated for each decomposition of a product (three levels shown as an example)

- How these process instances relate to each other.

Using the principles defined for creating the LCA, only one set of processes is part of the LCA. The additional levels are more instances of the same processes. The top processes (product) are part of the LCA, the lower processes (sub product) are additional instances of the same processes.
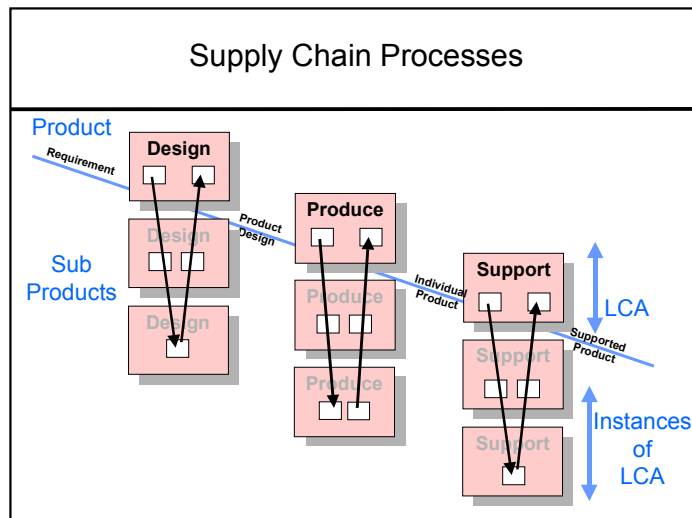
4.3.4.4 Decomposition of Design and Produce

Using the concepts defined above results in the following two IDEF0 diagrams of the decomposition of the Design and Produce processes. Note that two instances of the processes are shown, while this is not strictly IDEF0 notation, they are included to better describe how the processes relate to one another.
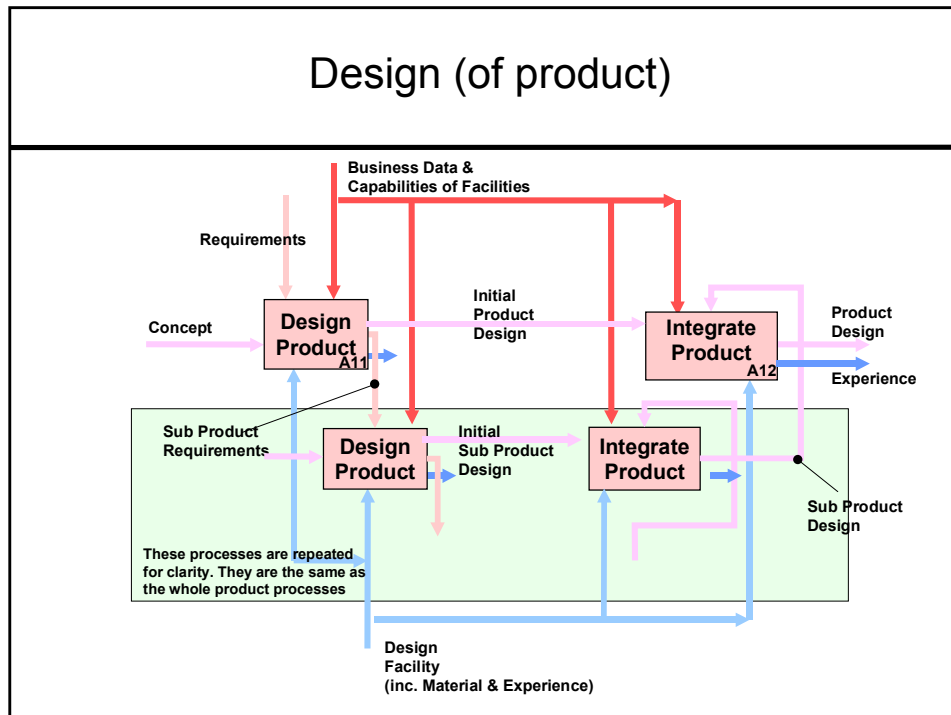
Figure 15 - Design Process (A1)
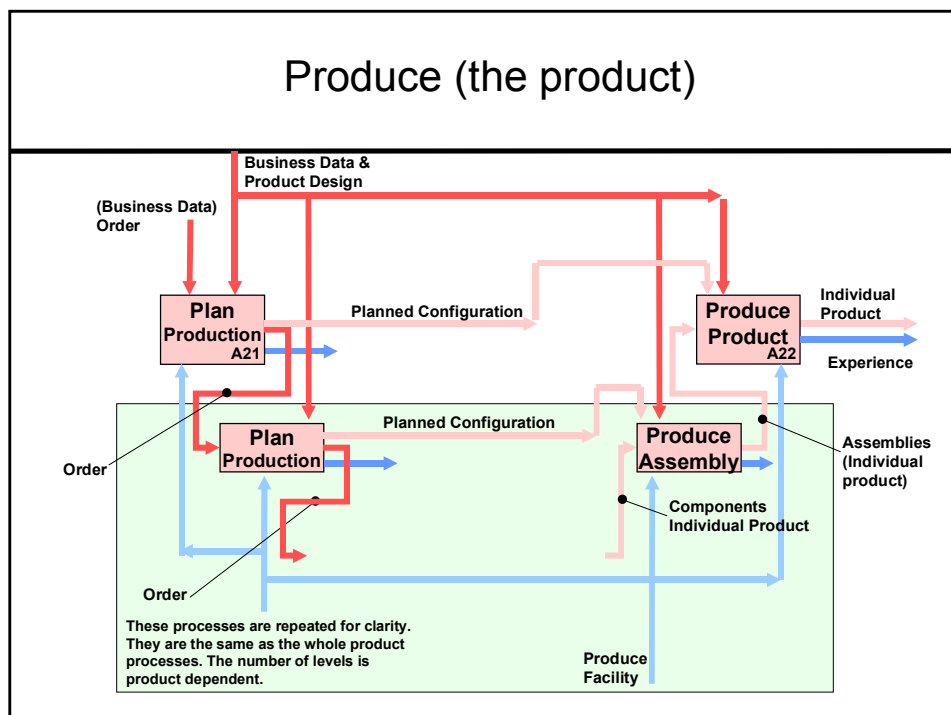
Figure 16 - Produce Process (A2)

4.3.4.5 Decomposition of Design

In the previous section, the first level of decomposition of the Design process was shown. Within the Product Design (A11) process a number of activities occur. These are shown in the following diagram.

Once a functional and physical design has been produced, it needs to be assessed to ensure its suitability for manufacture, supportability, and disposal. These activities add to the Product Design the definitions required for How to Manufacture, How to Support and How to Operate.
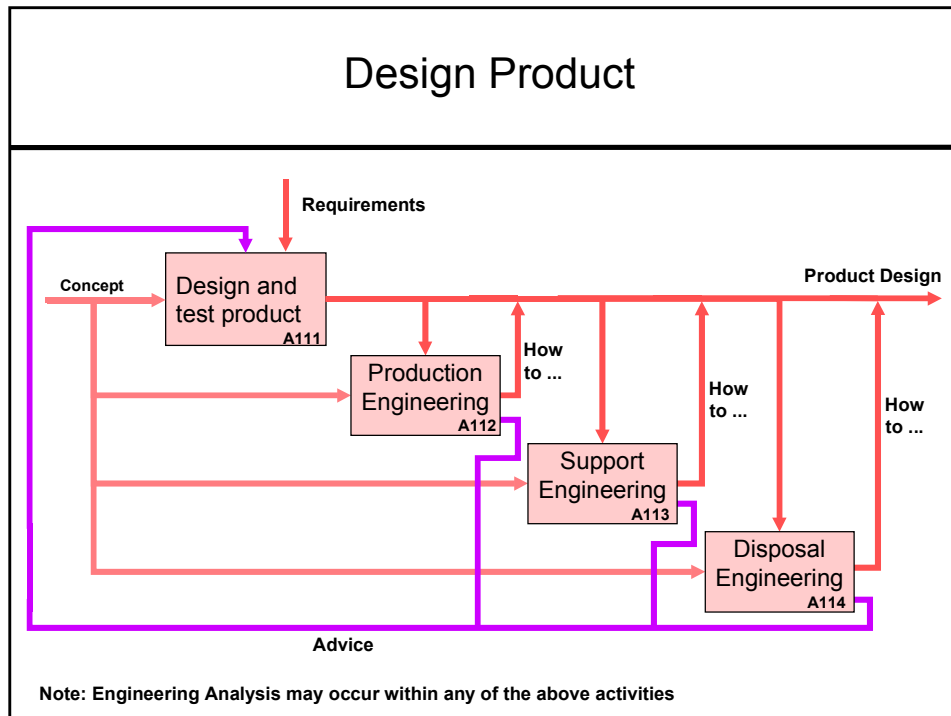
Figure 17 - Product Design Process (A11)

4.3.5 Testing

At many points in the Life Cycle Activities, there is a need to ensure that the resultant Product will have the desired properties.

- Within Design to predict the behaviour of the product when operated.
- Within Produce to validate the product meets the required specifications.
- Within Support to validate that repairs are acceptable.

There are two ways of ascertaining the properties of the product.

- By making a sample of the product and subjecting it to **physical tests**.
- By making an **analytical model** of the product and using this to predict the product properties.

Within Design, some combination of these two approaches is used; within Produce and Support, physical tests are the usual approach.

The diagram below illustrates the feedback from this testing back into the design process and is a decomposition of Functional & Physical Design (A111).
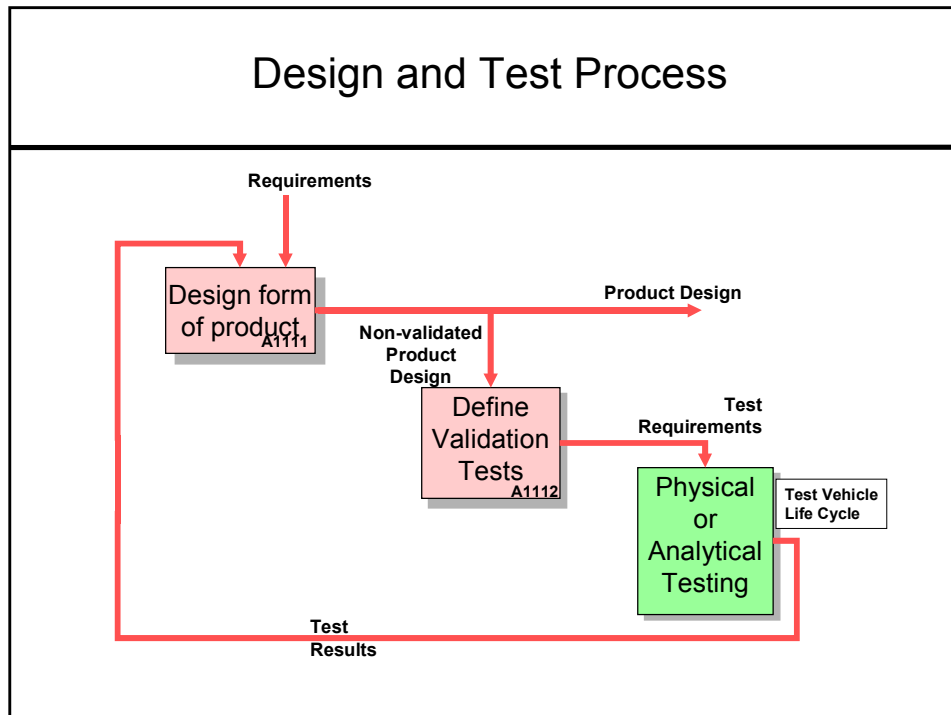
Figure 18 - Design/Test Process (A111)

Similar diagrams to the one above could be created for the other Life Cycle Activities.

Note that the third process is shown differently than the others. This is because the process deals with a different product (the test vehicle) and we are linking to the life cycle of this new product. This is explained further in the following section.

4.3.5.1 Relating the Testing Process to the Life Cycle Activities

To test a product, particularly when carrying out a physical test, involves

- **design**ing and **producing** a suitable test vehicle and equipment. Note that the product being tested may be modified to enable the test. This could involve the addition of instrumentation to record the behaviour of the product.

- performing the test to obtain test results, **operating** the test vehicle and equipment

- if the test is to be re-run then some **support** activities may be required

- **disposing** of the test vehicle and equipment

The life cycle of the test can be viewed as following the same one as a product. The following diagram outlines how the life cycles of a product and a test relate to each other.

Interaction with Testing Life Cycle

**Product
Requirement**

Design

Product Design

Produce

Material

**Individual
Product**

Operate

**Used
Product**

Support

**Maintained
Product**

Dispose

**Recycled
Material**

**Test
Requirements**

**Test
Results**

**Product
Requirement**

Design

Test Design

Material

Produce

**Individual
Product**

TEST

**Used
Product**

Support

**Maintained
Product**

Dispose

**Recycled
Material**

Figure 19 - Interaction between Product and Testing Life Cycles

This is even true of an analytical test using a computer program; see the mapping in the following diagram.The program and the necessary input must be designed and produced. The execution of the program provides test results. If problems exist in the program or the analysis model, then it is supported and finally disposed of.

Design/Analysis Interface

Requirements

Design

**Non-validated
Product
Design**

Define
Validation
Tests

Product Design

Analysis

**Analysis
Requirements**

**Analysis
Results**

Select
Analysis
Method

Idealise
Design

**Analysis
Model**

Execute
Analysis
Method

Design

Produce

Operate
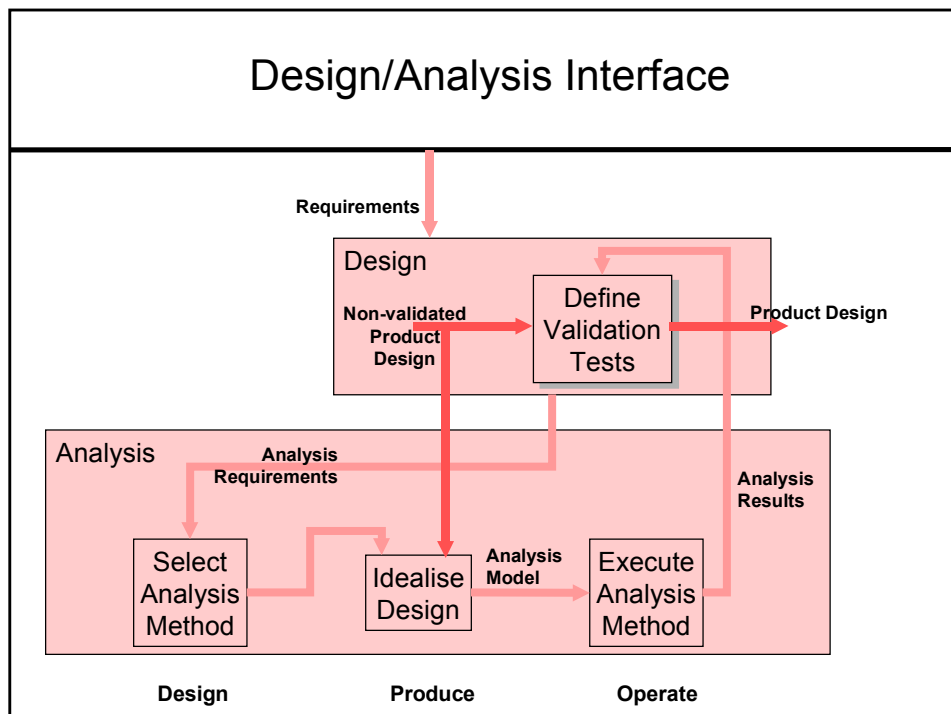
Figure 20 - Design/Analysis Interface

4.3.6 Delivery

In many industries, the movement of products from one location to another is an important activity. The Life Cycle Activities reference model does not show this process. However, there is a delivery process wherever a product needs to be moved. For instance, delivery of the product from the produce (manufacturing) facility to the operator (customer).
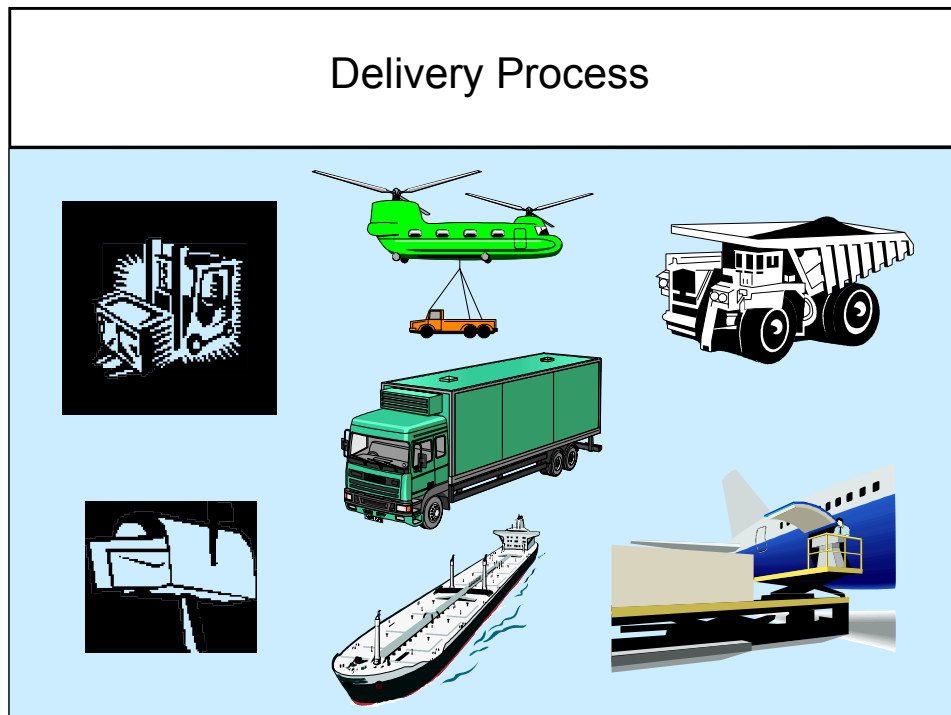
Figure 21 - Delivery Process

4.4 Relating the LCA to a Product Development Programme

To create a new product, industry carries out a development programme to design, test and develop the product. A typical product development programme consists of a number of phases, such as :-

Requirement Phase - defining the full set of requirements for the product

Concept Phase - defining (and re-designing) a concept design that the business is confident to take into full development

Development Phase - designing, testing, and re-designing the product so that it satisfies the customer requirements and can be produced in numbers

Series Production - manufacturing many of the product

Each of these phases will typically carry out a number of the Life Cycle Activities. The following diagram illustrates which of the Life Cycle Activities would normally be carried out in each phase and the product involved (the product being developed, production facility, or test vehicle). While the diagram shows the Design activity being carried out over a single period it is actually a series of repeated activities that refine the design from the concept through to a final design. Each iteration of the design improves its quality and reduces any risks.
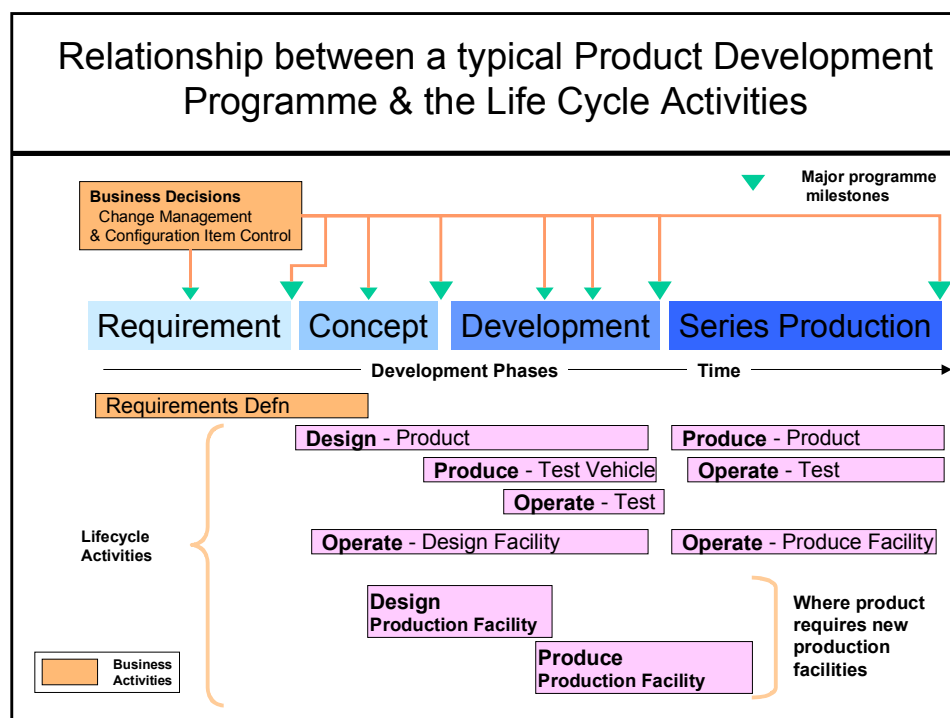
Figure 22 - Relationship between a Product Development Programme and the Life Cycle Activities
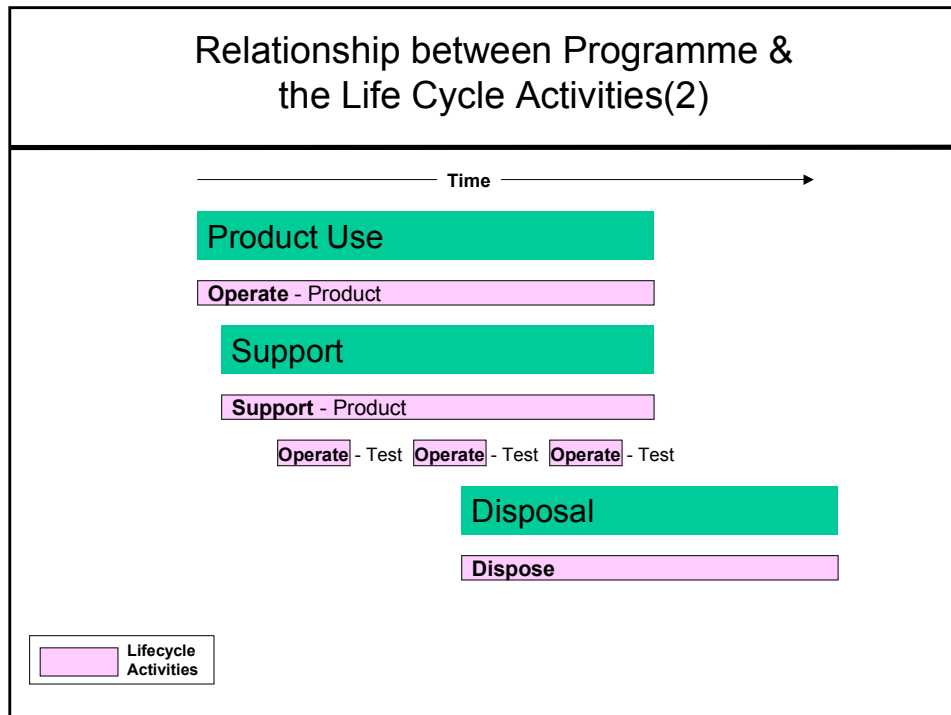
Figure 23 - Relationship between Programme and the Life Cycle Activities (2)

Once the product is delivered to the customer and starts being used then the focus moves to the operational use of the product, its support and finally its disposal.

5   Usage Scenarios

This chapter describes the industrial usage scenarios for the various SC4 standards. The development architecture and methods included in ISO 10303 are designed to support the principle objective of the standard: the specification of standardised descriptions of product data that are suitable not only for neutral file exchange, but also provide a basis for implementing and sharing product databases.

It is generally accepted that there is a significant industrial requirement for what is called "data sharing" and that "data sharing" is different from or beyond "data exchange". In addition to exchange, industry wishes to use standards to aid the access and archiving of data. The following sections describe these terms, with examples, and Annex D - Usage Scenarios and ISO 10303, page 95 discusses the relationship of these terms to ISO 10303.

5.1   Data Exchange and Data Sharing

The following simple real-world analogies can be used to illustrate the concepts of data exchange and data sharing.

5.1.1   Data Exchange - An Example

An account statement detailing a customer's banking activity is prepared monthly by a bank and sent to a customer via a Postal Service. The customer receives the statement and uses the information to balance his chequebook and track his financial position. A "data exchange" has taken place.
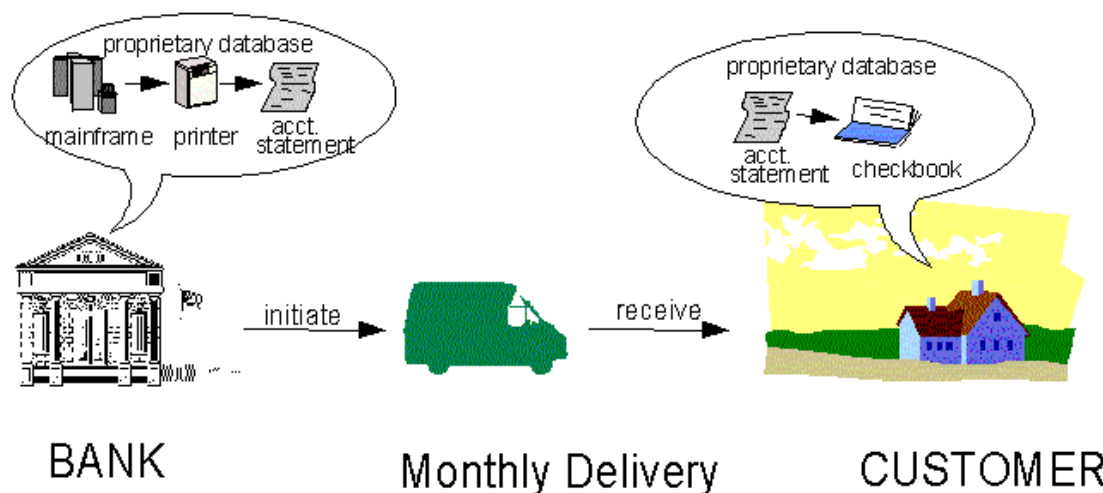
Figure 24 - Data Exchange Scenario - Example

Account information maintained by the bank has been transformed into a form the customer can understand (a statement), the information has been transported to the customer via an exchange mechanism (e.g. the Postal Service), and the customer has received and understood the information. Such an exchange has the following characteristics: -

- Initiated by data producer - Typically, a data exchange occurs upon the initiation of the party who originally produces the information, in this case the bank.

- Transformation to neutral format - The bank may choose among many different internal representations to effectively manage its account information. In order to communicate that information with the customer, however, a transformation must take place to convert the information into a form the customer can readily understand. In this scenario, the information to be exchanged includes not only

the data (numbers representing dollar values), but also the *context* of that data. In this case, the context is represented by the column titles and descriptive text, which accompany the numeric data on the statement. Without this contextual framework, the customer would have a difficult time understanding the information.

- Redundant copies of data - Once the exchange has taken place, there are now two copies of the account information: the account information represented internally at the bank and the statement now in the possession of the customer. Typically, the customer will use the account statement to maintain his own account information independent of the bank.

- Discrete event in time - A data exchange occurs as a discrete event in time. Once the exchange has been accomplished, the information at the "sending" side (the bank) may change without notice to the "receiving" side (the customer). The information passed during the exchange is simply a snapshot of the data as it existed at the time of the exchange. If this new information is to be passed along to the customer, another data exchange must take place. Similarly, if the customer wishes to respond in some way to the account statement, the customer must initiate a new data exchange in which his response is sent to the bank.

5.1.2 Data Sharing - An Example

Unlike data exchange, the definition of data sharing is not as easy to agree on. This is true because there are many different implementation objectives for data sharing and many different ways that data sharing implementations can be created. At an abstract level, data sharing means data stored in one system can be shared by other systems. Conceptually, a sharable data instance needs only to be stored once in a single place and used for many purposes by many systems. The term "share" means to use, own, or receive jointly; it is also defined as a portion of a whole, which is given or assigned. If we use these definitions, data sharing is not the act of transferring a snapshot of the data, but the joint use and ownership of the data.

Consider one example (as illustrated) of data sharing in the context of the banking analogy presented above.
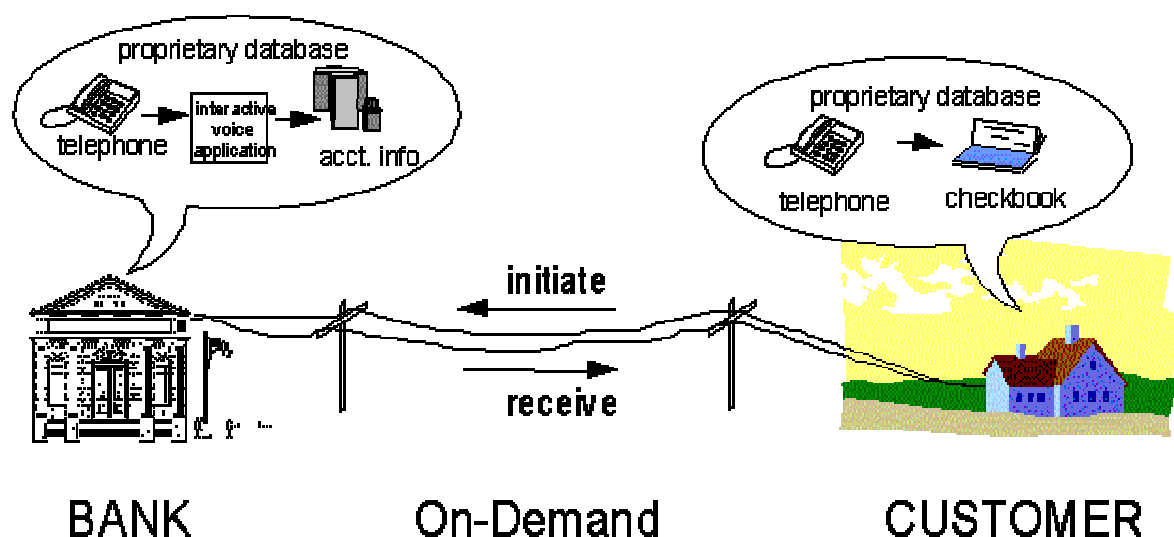

Figure 25 - Data Sharing - Example

Rather than mailing an account statement every month, the bank may implement a touch-tone telephone system to pass along information to its customers. A customer may call the bank and use the push-buttons on the

telephone to enter his or her account number and navigate menus to access and update his or her account information. In this case, data sharing has the following characteristics: -

- <u>Initiated by data receiver</u> - Typically, data sharing occurs upon the initiation of the party who desires/receives the information, in this case the customer who initiates the telephone call.

- <u>Data on demand</u> - Because the telephone system provides the customer with the latest account information at the time of the phone call, the customer need only call at the time when the data is actually needed. In addition, the customer chooses the content of the information he or she wishes to receive by selectively navigating through the touch tone menu system.

- <u>Context embedded in protocol</u> - The context of the information received by the customer is partly defined by the specific steps, or *protocol*, the customer uses in interacting with the phone system. For example, in response to the phone system's prompts, the customer may press "1" to receive checking account information and then press "2" to receive current balance or "3" to receive most recent check number that has been cashed. The actual context of the final numeric data received by the customer is defined by the series of steps taken to receive the data.

Although the telephone banking system example helps to illustrate some of the characteristics of data sharing, there are additional characteristics that fall out of the scope of the example above: -

- <u>Single Data Instance</u> - In most data sharing systems, only one instance, or master copy, of the data is maintained. Other interested parties may access the information as needs require, but only one copy is considered to be the updated, legitimate repository of the data.

- <u>Read and Update</u> - Data sharing often encompasses more than just a retrieval of information. Facilities often exist which permit updating of the single data repository by multiple parties. In this perspective, data sharing is a "two-way" street which allows both information access as well as information updating.

5.2 Data Access

Data access is closely associated with the concept of data sharing. Access is defined as the right or means of approach. In the data world we use the term as the ability to read information, while not being able to change or update the data. Therefore Data Access is a subset of the Data Sharing example above. In that example the customer would be able to read their bank information but would not be able to change any entries.

5.3 Data Archive

The word archive is defined as a collection of public records or the place that these are kept. From the industrial viewpoint data archiving is the process of storing data (product data) for a long period of time for some commercial or regulatory authority reason. At some point in the life of data, a business decision may be made to archive it. It will then be stored in a secure place (Archive). Years later when the data is next required it must be retrieved and understood. Industry needs to be able to process the data in the system that is available when the data is retrieved. It is often impractical or impossible to keep the system that was used to generate the data. Because of the large quantities of data involved with complex products, the data may well be kept during this period on some form of off line medium (magnetic tape, disk, and optical disk).
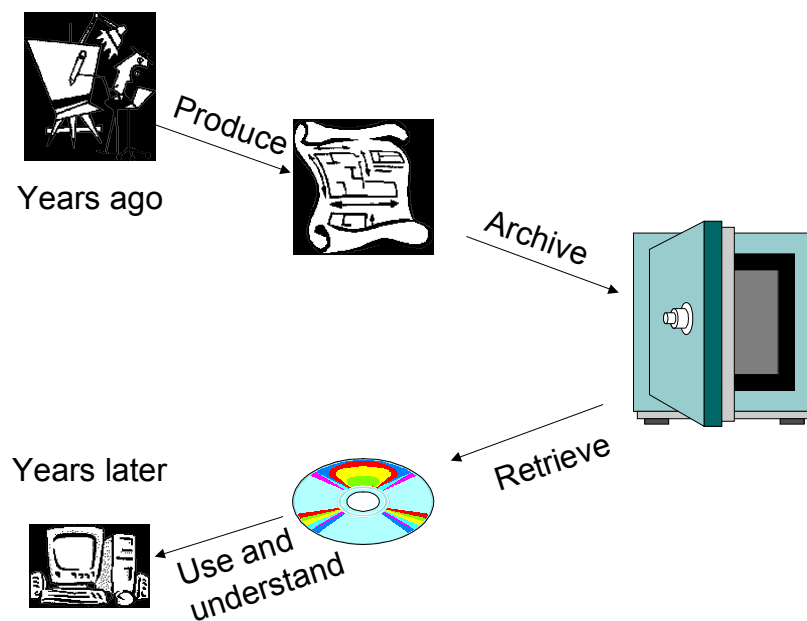
Figure 26 - Data Archiving

Data archiving is similar in some ways to data exchange. A sending system may translate data from its internal format and encodes it into an established neutral format. Rather than transferring this file, the file is stored for a period of time, for some products this may be as long as 50 to 100 years. At a later date, the file is retrieved and transferred to the receiving system where the data is translated into the internal format of that system. This system may be a future version of the one that generated the data or may indeed be a completely different one.

To achieve a successful Data Archive facility requires a number of issues to be addressed. These include

- Understanding of the business processes to ensure the correct data is archived.
- Provision and maintenance of a secure data storage facility that takes into account the life span of the storage medium.
- The identification of archived data so that the correct data can be retrieved in the future.
- The format and description of the data that is archived so that it may be understood in the future. For instance, if data is stored in a proprietary format for many years, the original system may not be available to retrieve and use it.

5.4 Industry Usage

Within industry, data exchange, sharing, access, and archiving will be used in many ways. The following sections give examples of possible usage.

5.4.1 Data Exchange

Data exchange will be used between companies and between companies and government or regulatory authorities. In particular, it will be used where the use of a data sharing/access environment is either not desired, cost effective, or cannot be created in time.

- Between Companies,
    - From Customer to Supplier,
    - From Supplier to Customer

- Between Company and Authority and/or Government Division
  - From Authority and/or Government Division to Company
  - From Company to Authority and/or Government Division

5.4.2 Data Sharing/Access

A data sharing or access environment will be used where a higher degree of integration between users/partners is desirable. These are likely to be within a company and/or between companies within a joint consortium .

- Head Office and Business Units
- Predecessor and Successor in Life cycle Activities
  - Design, Produce, Operate, Support and Dispose
- Concurrent Engineering Partners
- Functional Design and Production Engineering
- Functional Design and Engineering Analysis
- Engineering Analysis
  - Computational Fluid Dynamics and Stress / Strain Analysis

5.4.3 Data Archiving

Data Archiving is the long-term retention of data for a commercial or regulatory authority reason. Typical reasons for retaining data are:

- For effective Customer Support with regard to Product Liability
- For effective re-use of the Design Data (as a basis for product improvement or a new product)
- For transferring the legacy data to be accessible by a new technology (e.g. Data Modelling, CAD/CAM, Engineering Analysis)

Typical data that is retained includes:

- Design and Analysis Data
- As Designed Configuration
- As Built Configuration
- Process and/or Inspection Records
- As Maintained configuration logs

5.4.4 Database Transactions

In all of the above types of data usage, industrial practice requires efficiency in the retrieval and access of data. This is only possible when one can structure queries against a data repository in such a way that full sets of aggregated data can be obtained via a single query. It is a requirement that any SC4 standard that defines such interfaces must accommodate these types of queries to allow efficient implementations. Any details of the queries that need supporting are outside the scope of this document and should be issued as additional documents.

6   STEP Data Concepts

The purpose of this chapter is to

- note the major types of **industrial data** defined in the Life Cycle Activities reference model and describe the major **relationships** between them

- describe major types of **relationships** present within industrial data

- describe certain ways of **categorising data**

- define a **product data backbone**, which, when supported by Application Modules and the Common Resources and incorporated into Application Protocols, will ensure an essential level of interoperability between Application Protocols.

6.1   Types of Industrial Data and Relationships between them.

It is the information flows in the Life Cycle Activities (LCA) reference model that industry will wish to exchange and share between companies. The LCA shows that there are four types of industrial data that standards need to support.

- **Business Data**
- **Product Requirements**
- **Product Design**
- **Individual Product** instance

All of the types of data in the LCA are one of the above types.

6.1.1   Typical Scope of Information Flows

To identify the Application Modules that will be required to support the various product types, we need to decompose the information flows defined above. The following sections give examples of what these information flows would contain. The product being considered is a typical mechanical product, perhaps biased towards an aerospace product.

6.1.2   Business Data

Business data is a control on all the life cycle processes. It will typically contain: -

- Authorisation or approval to proceed
- Contract
- Orders
- Project Plan / Programme
- Quality System Procedures
- Laws and Regulations
- Health and Safety Legislation
- Policies

6.1.3   Product Requirement

Product requirements consist of a set of desired properties that the product is expected to exhibit.

A typical example would be: -

- I want a jet engine whose thrust is at least 30000 lbs. and whose weight is less than 10000 lbs.

  This is of the form: -

  I want a product of class Jet Engine whose **properties** are

  1. Thrust greater than 30,000 lbs.

  2. Weight less than 10,000 lbs.

There are also requirements on the operation of the Life Cycle Activities such as when the product should be delivered. In this paper, this type of requirement is a input to the **business** level processes and is passed onto the Life Cycle Activities as a constraint within Business Data.

6.1.4 Product Design

The Product Design will typically consist of a number of items

- the **functional** design and properties of the product, how the parts of the product function and interface with each other.

- the **physical** design and properties of the product

  Typical physical properties for manufactured products would be: Shape, Structure, Position & Orientation in structure, Colour, Location in World, Material, Quantity

- the **behaviour** (expected/predicted) of the product

  Examples that would be important when the product is a jet engine are: Mechanical Integrity, Observables, Aerodynamic, Noise, and Performance

  Similar lists could (and should) be created for the products of interest to each industry.

and

- any constraints the Design process wishes to place on the downstream processes (such as **How To** produce or operate the product)

  Examples of the type of information that could be used to constrain the various life cycle processes, again from the viewpoint of a mechanical product are: Input Material Definition, Plant / Workshop Facilities, Tooling, Consumables / People Skills, Quality System Requirements, Health & Safety Specification,

  It should be noted that the items defined here are very similar to those defined under Business Data.

6.1.5 Individual Product

This contains the actual behaviour of the product and its physical and functionally properties.

- Physical

- Functional

These are equivalent to the product design information but are the observed or measured values rather than predicted ones.

6.1.6 Major Relationships between LCA information flows

When sharing this information, the relationship between the data types is very important. There are some major relationships between the information flows in the LCA that need to be used. This section tries to describe some of these major relationships.

The following diagram shows two ways of representing two of the most important relationships, those between the **product requirements**, **product design** and the **individual product**.
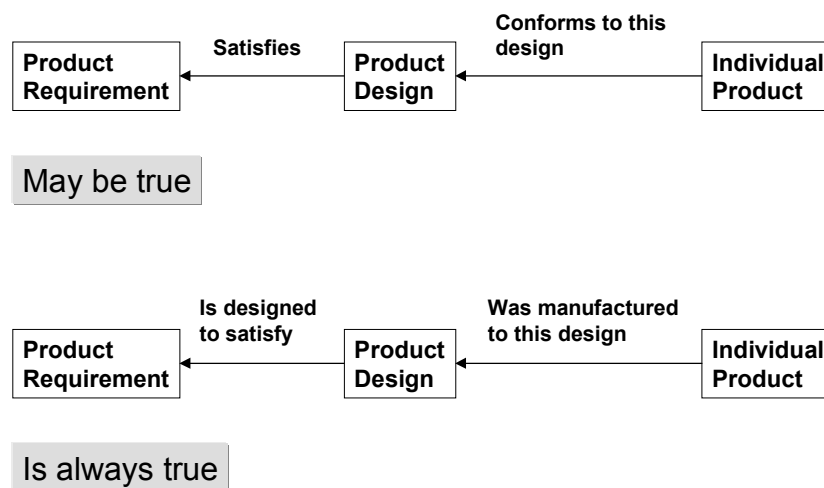
Figure 27 - Relationship between LCA Information Flows

It is important to ensure that the relationships are correctly defined. While it may be true that an actual product does conform to a design and in turn this satisfies a set of requirements, this can only be known by checking the product against the design and the requirements. The relationship must be defined in a more general way.

Note that these relationships may seem vague. It is **NOT** always possible to say that the Product Design satisfies the Requirement. The Design process may not have completely achieved that goal. It is however always possible to say that it was **designed to satisfy** the Requirement. A more general way of expressing this is to say the Design process had the Requirements as a control and it produced this Product Design. Only by comparing the Product with the Requirement is it possible to say whether the intent was achieved.

These are specific examples and they do not cover the complete range of relationships that could be required. To generalise this, we need to look at the business process that created the relationships between the various information types.

The next diagram shows the IDEF0 notation for a process and a data model (in EXPRESS-G notation) that relates the information flows to each other via the process.
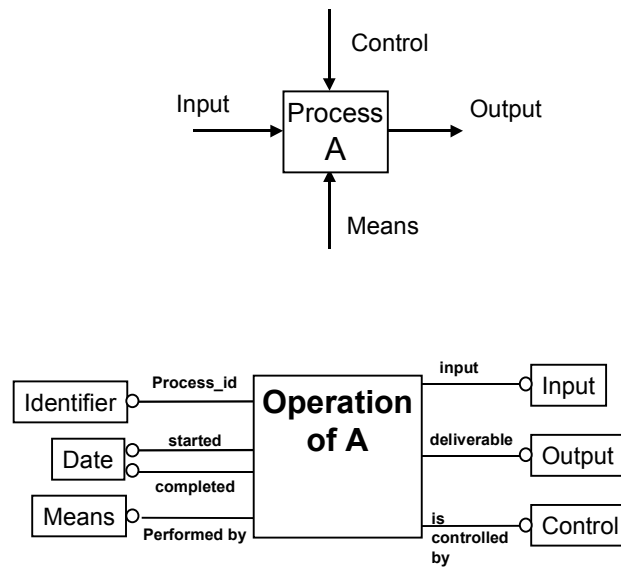
Figure 28 - Relationship between IDEF0 Flows

Applying the concept above to the **LCA** processes gives the diagram below. Note that the subtype/supertype relationships are shown by the thick lines.

- The individual activities or processes in the **LCA** are subtypes of a general **Activity** entity. The **Activity** is identified and can have start and end dates recorded.

- The **Activity** uses a **Product** as an input and produces a product as an output. The **Product** has a number of subtypes, which are the information flows in the **LCA**.

- The **Product Requirement** is a control on the **Design** activity.

- The **Product Design** is a control on the **Produce, Operate, Support** and **Dispose** activities.

- The Activity is carried out by the means, which is the Design, Produce etc Facilities. These are roles that a Facility plays and hence the means is shown as **Facility**. Since **Facility** is a real object it is shown as a subtype of **Individual Product**.

- **Business Data** is shown as a control on all of the activities.

- **Facility Capability** is a control on the **Design** process.
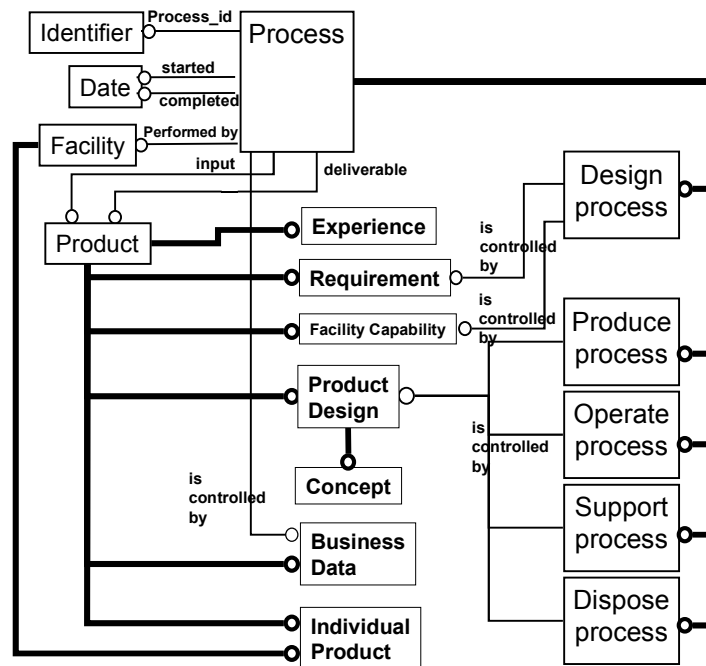
Figure 29 - LCA Information Flow Relationships

6.2 Major Relationships

This section describes some of the concepts and major relationships that exist between industrial data. These have led to some of the methods of categorising data described in later sections and the concepts in STEP and the Product Data Backbone.

6.2.1 Properties, Representation and Presentation
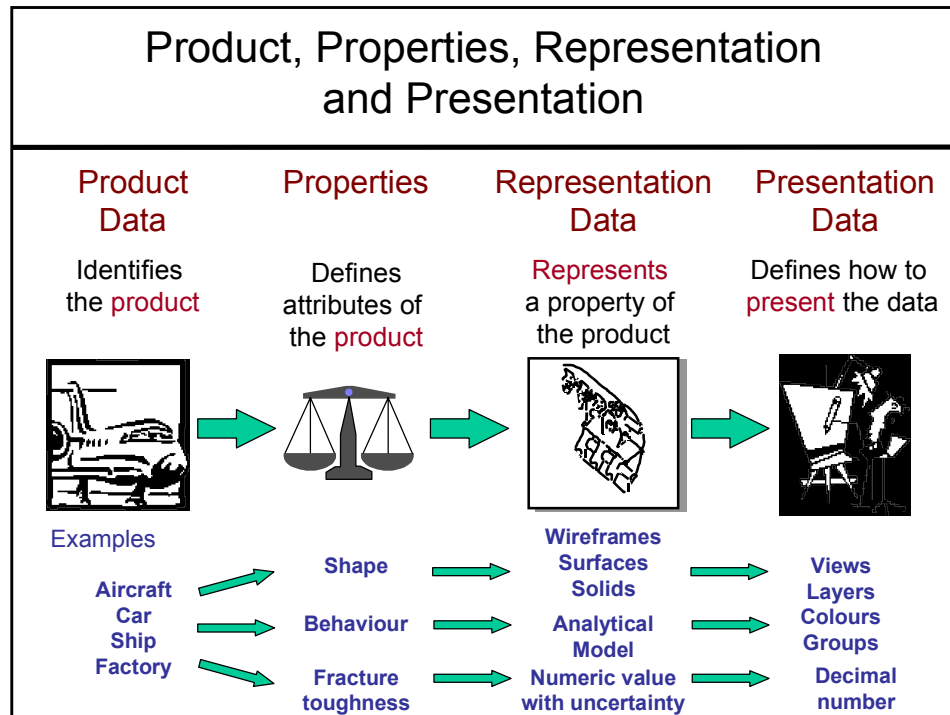
Figure 30 - Product, Properties, Representation & Presentation

This picture graphically describes the difference between: -

- 'Product Data' that identifies the product

- Properties that are the concepts that characterise a product, e.g. shape, structure, structural behaviour, material type, weight.

- Representations of those Properties, these provide ways of describing the properties. Representations only stand in for the properties and they could also be used to represent things other than product properties.

  - e.g. geometry can represent the shape of a plane, the path of a space shuttle, or the border of a drawing.
    Note that geometry means curves, surfaces, and volumes within a mathematical space and defined by mathematical functions, and not curves, surfaces, and volumes in physical space.

  - The choice of how product shape is represented is an industry decision; for example, in theory you could represent the shape for manufacture by a finite element model.

  - The weight of the product may be represented by a value (212.304) with units (kilograms)

- Presentation data which contains no Product information but defines how information should be

displayed on paper, screen etc.

The definition of this can range from simple to complex.

- the format to use when displaying the weight of the product (212.30kg)

- the definition of how to display complex surfaces on a drawing.

6.2.2 Product and Properties

Properties are the concepts that characterise a thing or a product, e.g. shape, structure, thermal behaviour, material type. The picture above implies that Properties only characterise what is generally thought of as a Product. This is not the complete picture; we need to be able to assign Properties to other things such as the environment. Within STEP, the definition of the word Product is general enough to include such items.

Consider, for instance, the behaviour of a product in some environment. The behaviour of the product will be dependent on its environment.
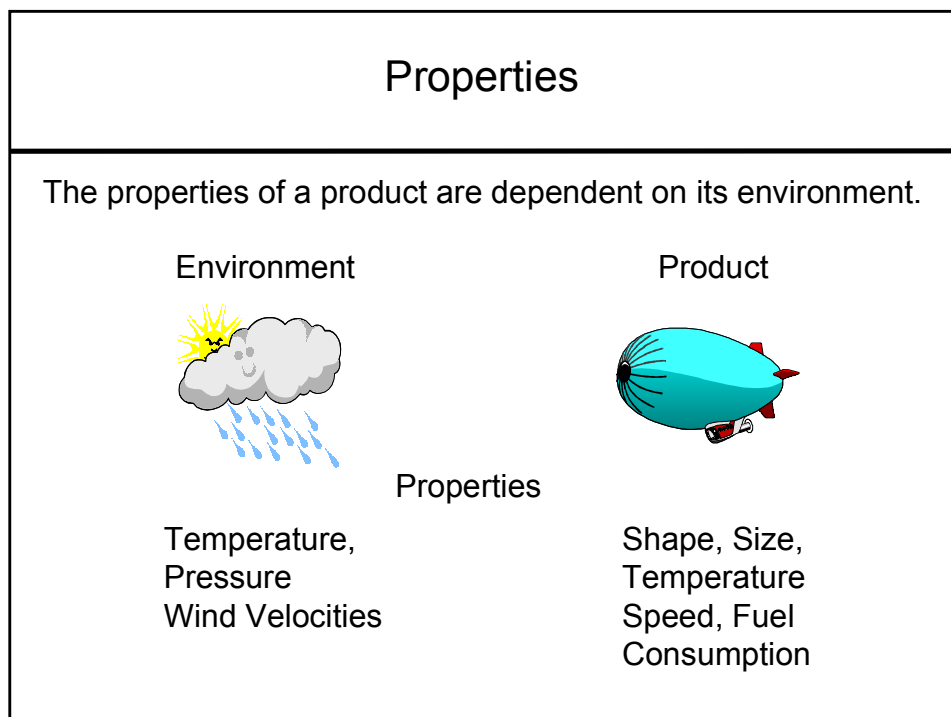
Figure 31 - Properties

Even for a simple mechanical product its size (and shape) will be dependent on the temperature (and possibly pressure) of the environment. As the temperature changes, the product will expand or contract. Whether this is important will depend on the type of product.

When exchanging the shape of a product, the properties of the environment must also be supplied.

Both the Product and the Environment have properties that need to be understood before the behaviour of a product can be predicted.

6.2.3 States of a Product

Within industry, the properties of a product are usually discussed in relation to the state of the product. For instance the fuel consumption of an automobile is often stated as the *miles per gallon at 60 miles per hour* (or in

some other units of measure), at *30 miles per hour*, or even *"under normal urban driving conditions"*. Each of these is a particular state and the properties of the product may be different at each state.

States exist for a particular period of time and an activity is required to change a product from one state to another. The requirement on a product can be that it will have certain states and particular behaviours at each state. The product design will then try and satisfy those requirements.
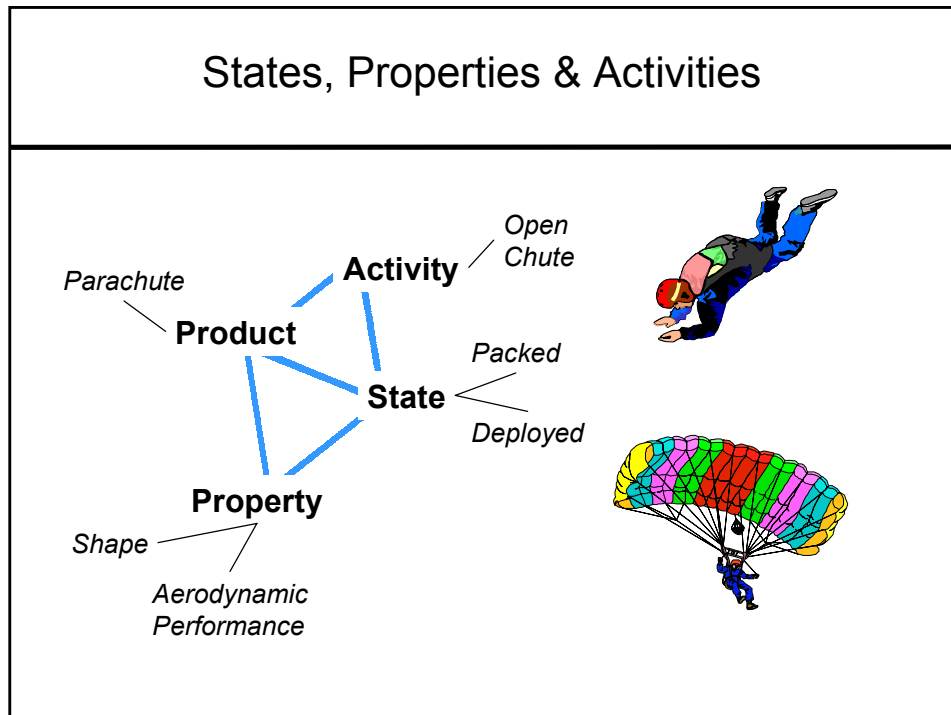
Figure 32 - State & Properties

6.2.4 Means and Product

Looking at the Means for the Life Cycle Activities, we see that the facilities that design, produce, operate, support, and dispose of products are products in their own right. Someone has designed and built them and they are then operated and supported. The facilities consist of many items: -

- Facilities, Buildings
- Materials
- Tools
- People
- The knowledge gained from previous work, process experience and know-how
- Etc.
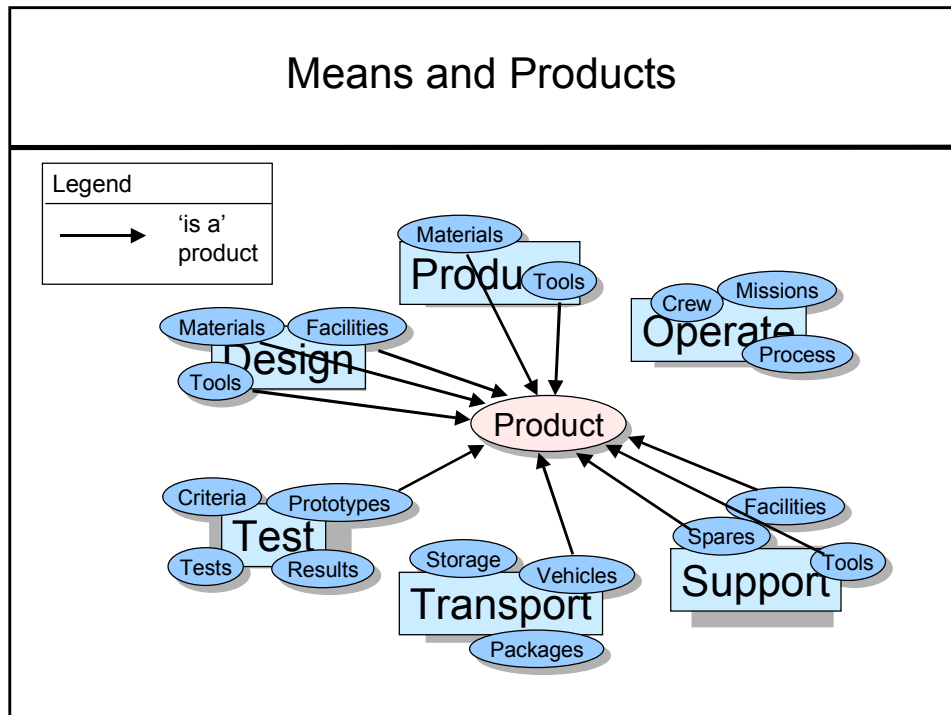
Figure 33 - Means and Products

There are at least two viewpoints that can be considered when creating information models of these areas:

The first viewpoint is to describe the items from within the Facilities. For instance, within the Produce Facility there are items such as materials and tools.

The second viewpoint is to consider these items as just products. Each of the items is an individual product in there own right and hence will go through (are within) their own 'product life-cycle'. This is shown by the 'is a' relationship to Product.

If we can consider the facilities as products then the general information models for a product can also be used for these "means" or facilities. The use of the classification concepts described in the following sections can be used to record the viewpoint or context of the user of the data. The classification data would allow the product data to be defined as Facility data or not.

6.2.5 Different Viewpoints and Product-in-focus

How you describe an object (and what you call it) often varies depending upon your particular viewpoint at a point in time. For instance a block of metal would be

- a product to the company selling it
- material to a company making something else from it

To achieve interoperability of standards, it is important to recognise these are different viewpoints or user contexts of the same thing and to try and model the fundamentals of the thing in a manner that will support different viewpoints.
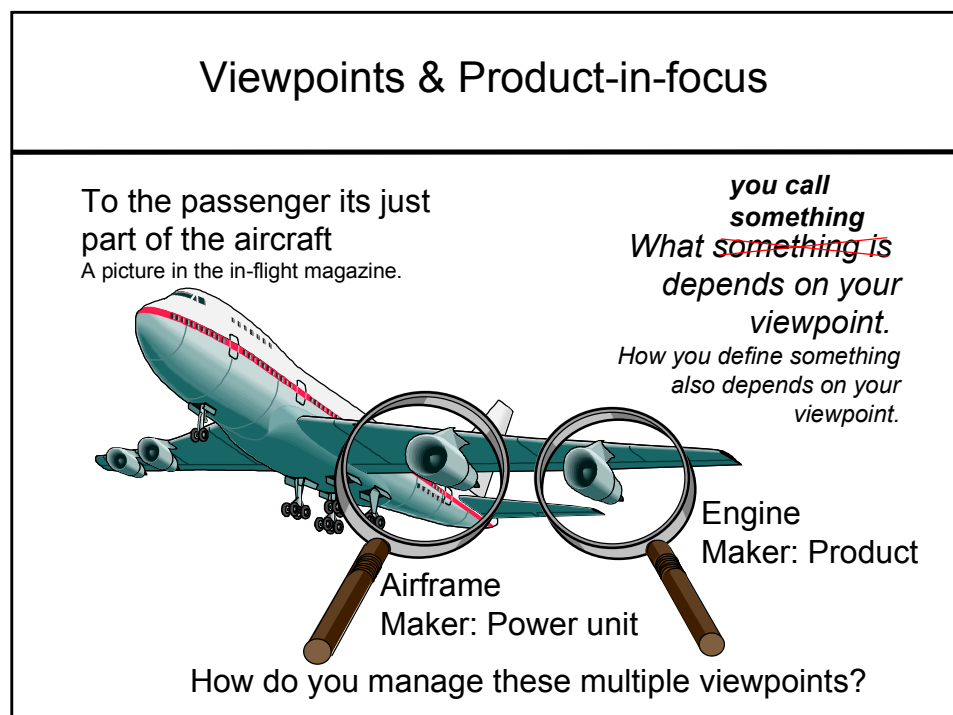
Figure 34 - Viewpoints & Product-in-focus

Product-in-focus

To ensure the standards handle these different viewpoints it is useful to focus on a single product at any one time. For instance when considering a standard in regard to an aircraft, the products that make up the aircraft, and the aircraft's production facilities, you can take each of these in turn (as the **Product-in -focus**) and consider whether the standard (or this framework) supports these items

Classification

To record some of the different viewpoints the concept of classification that is described in the following sections can be used.

6.2.6 Classification and Typical Configuration

There is a need within specific industries to model and exchange industry or product specific information. There

are some general concepts that can be defined.

'Is a type of' - the classification of different types of product. Since all of the concepts being modelled are themselves products they have a 'is a type of' relationship to Product.

'Consists of' - the specification of the composition of a product. **Note:** that there may be alternative or multiple ways for the decomposition of a product that reflect different viewpoints.

This second concept can be separated into two.

'Actually Consist of' - the specification of the make up of a particular product.

'Typically Consists of' - the specification of what composes a typical product, e.g. ships typically consist of a hull, engine etc.

There are two approaches to modelling the above relationships. Take, for example, the 'consists of' relationship. This can be modelled either specifically or generically.
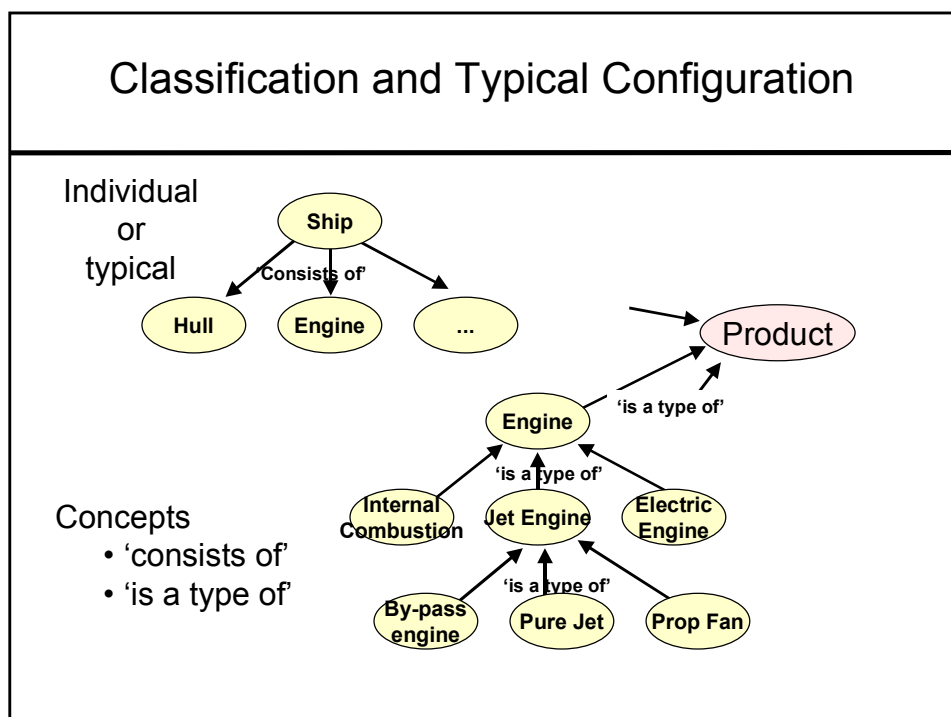
Figure 35 - Classification and Typical Configurations

Specifically

The data model is similar to the picture above and has specific entities (or objects) such as 'ship', 'hull', etc. that describe the components of a ship.

Generically

A generic model would have entities like 'product' and a general relationship that allows products to consist of other products. The specific information about ships would then be instances that populate this model.

It is, in fact, valid to use either of these approaches; the best option depends on the uses to which the model will be put.

6.2.7 Classification and Properties

To set up collaboration between companies, industry needs to agree what properties of a product are important and are to be exchanged (and then what representations should be used for each property). For instance, when passing data between a design organisation and a manufacturer, the shape of the product is important but its behaviour may not be.

In a previous section, the concept of classification of products was discussed. The EXPRESS-G diagram below shows one method of modelling this concept.

Products that have the same characteristics (types of properties) can be classified into a **Class of Product** by the **Classification of Product**. For instance a particular ship could by classified as a Destroyer. It is useful to share this information as it describes what the product is.

The Product Properties that are relevant can also be linked to this classification. (**Class of Product**). For instance, electrical properties are of interest if the product is a video recorder but probably not of interest if the product is a chair. **Characteristic Properties of a Class** allows this information to be held. It would allow electrical properties to be linked to the class of electrical product but not to the class of non-powered chairs.

It is these properties and their representations that industry will exchange. To enable exchange, industry must agree the properties that are to be exchanged and hence need to share this classification information.
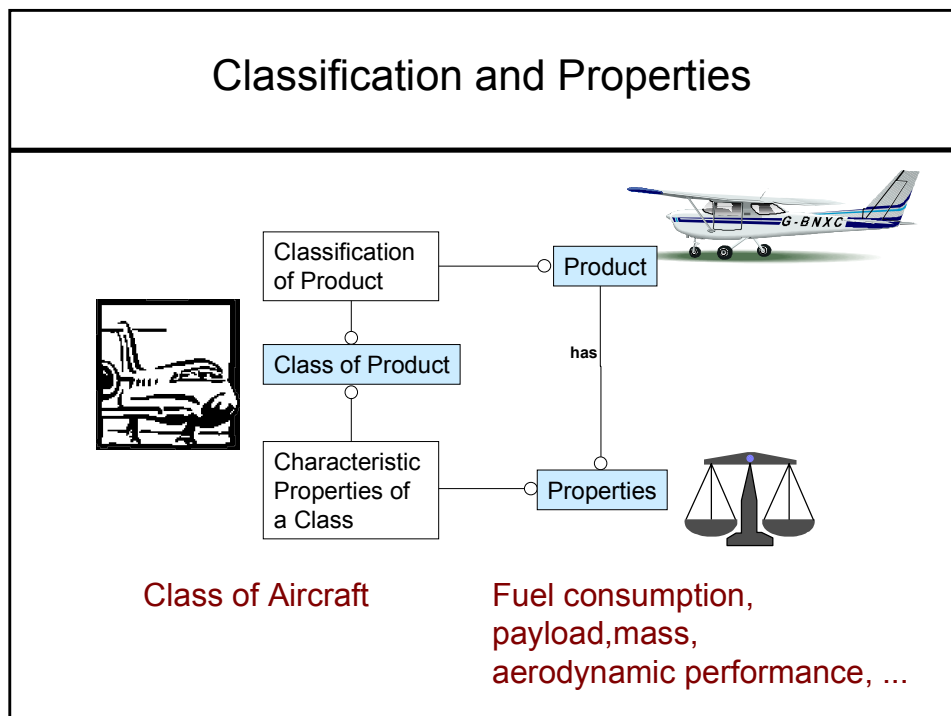
Figure 36 - Classification and Properties

6.3 Data Backbone

This section proposes a method of categorising the types of concept discussed above and the concept of a data backbone. The backbone is a set of core concepts on which most Application Protocols should be based. It is believed that these concepts will be defined in Application Modules, using or extending the Common Resources and some subset of them will appear in most if not all Application Protocols. This core of concepts would therefore form a **Backbone** underlying Product Model Data and provide a minimum level of interoperability between Application Protocols.

The categorisation method is the Industrial Information Model. This model is used in later sections to support the concept of a data backbone.

In addition to the above, the section introduces a planning notation that can be used at the early stages of designing a set of modules.

6.3.1 Industrial Information Model
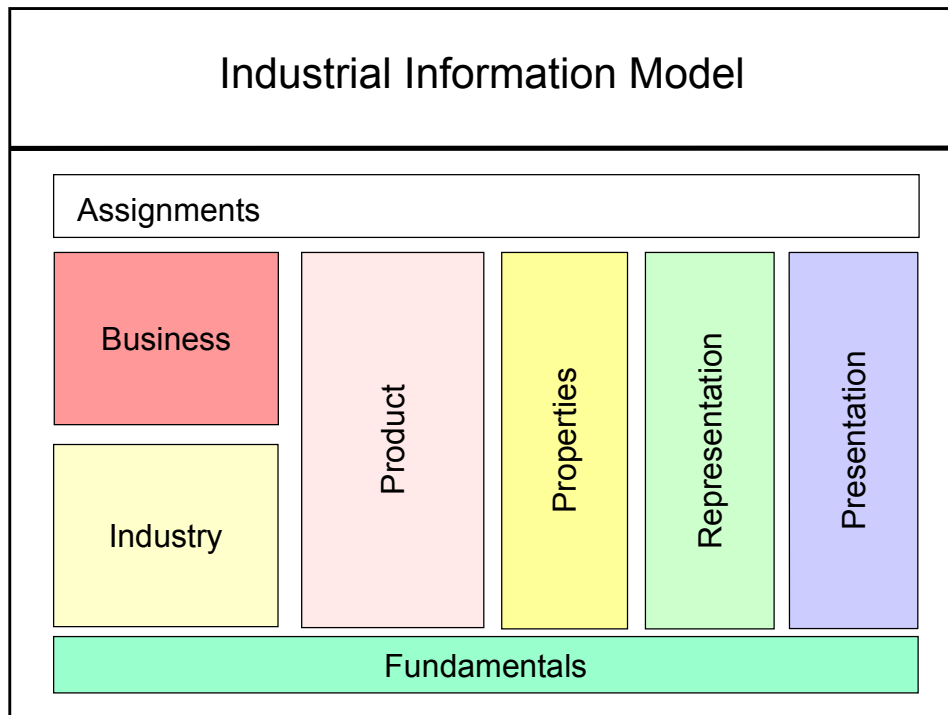
Figure 37 - Industrial Information Model

The IIM is derived from the Life Cycle Activities together with the concepts discussed in the previous section that described major relationships.

It is realised that not all the concepts within STEP/SC4 standards can be mapped to the IIM categories. It is believed that the all of concepts in the lower level / more basic Application Modules will fit into one of the IIM categories. A later section describes a Data Backbone of concepts that should provide the core of most Application Protocols. These concepts are mapped onto the IIM.

Business

These are concepts concerned with the operation of and control exerted by business.

The links between modules in this category and the product information will be to record the control that business management had on aspects of the life cycle of the product. For example, this category would include Project Management, Business Planning, Change Management, and Purchasing.

Product

This category covers concepts that are characteristic of all Products; it includes the identification of a Product, its various definitions and its structure. Property concepts will link to product concepts to allow the more detailed information about the product.

Examples: Product Identification, Product Structure, State

Properties

Properties are the concepts that characterise a thing or a product, e.g. shape, structure, thermal behaviour, material type.

Representation

Concepts that are used to represent attributes, properties or characteristics of a product but could be used for other purposes. This includes concepts such as

- Geometry that can represent the shape of a product
- Finite elements that can represent both the shape and behaviour of a product
- Bills of Materials or Product Structure Trees that can be used to represent the structure of a product

Presentation

Concepts necessary to create a presentation of product information through some form of sensory method. The sensory methods would include visual, tactile, auditory, and olfactory.

These concepts could be used to present information other than product information, but in the context of STEP they are only meaningful if associated with product information directly or via a representation of product information.

Examples: Surface Appearance, Annotation, Drawing, and Document.

Assignments

Assignments contain the concepts that allow the others to be linked together to satisfy an industrial need. For instance, linking a geometry representation to the shape property. These concepts are needed to allow reuse of concepts and to allow industry to choose the appropriate combinations. For instance, geometry can be used for more than just shape properties and which geometric representation will be used is decided by industry.

Fundamentals

These are fundamental concepts that: -

- Are very general in nature
- Can be used by modules in any of the other categories above
- Could, in principle, be used independently of STEP

    Examples: Date, and Colour (Colour can be used to describe a property of not only a product but also of the presentation of a line, surface, or text)

Industry

This category is an extension of the **product** category above and covers product concepts that are specific to a particular industry or product type. For instance if a particular product is identified in a more specific manner.

Examples: Part Identification, Part Structure

The following diagram shows a sample set of data concepts mapped onto the IIM categories.
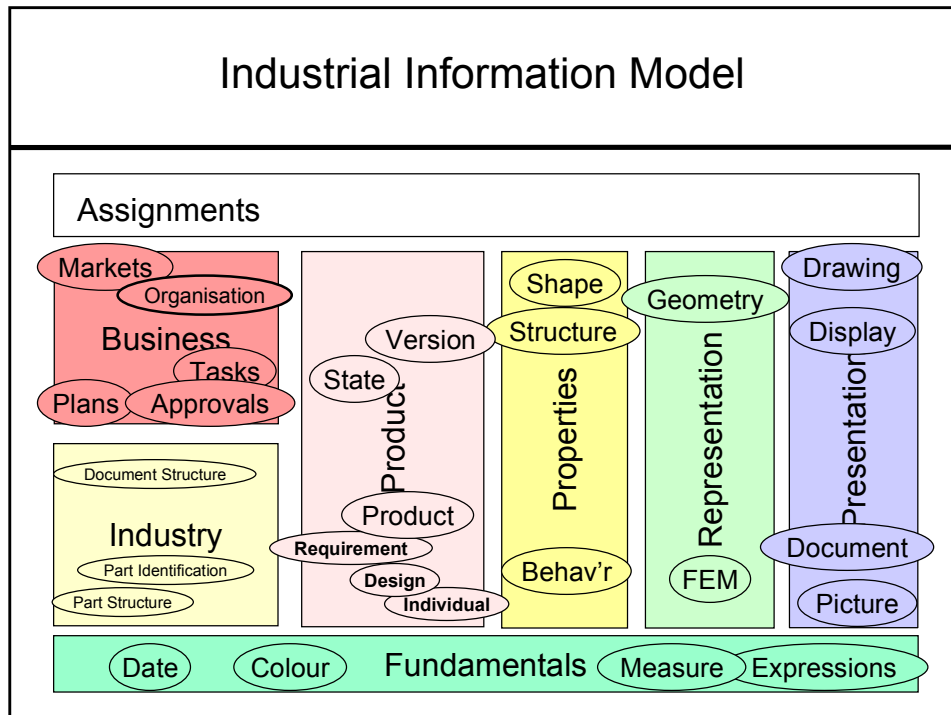
Figure 38 - Mapping Concepts to the IIM

6.3.2 Planning Model Notation

The diagram shown here defines a notation that can be used to show types of relationship between concepts. This type of diagram can be used to plan a set of Application Modules and the relationships between them prior to defining the detail of each module. This notation is used in subsequent sections of this document.

Planning Diagram - Notation

A depends on B

A may select B

A may specialize B

A — mandatory → B

specialisation

A → C (thick arrow)

B ⋯optional⋯→ D

solid line : mandatory requirement
dashed line: optional use
thick solid line : specialisation (subtype / super type)
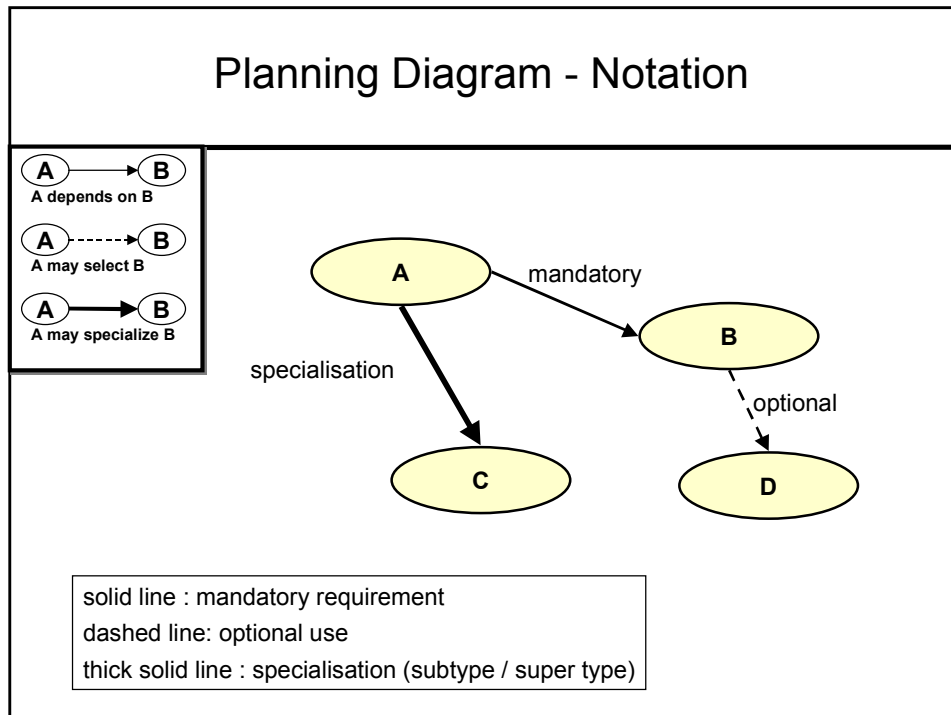
Figure 39 - Planning Diagram - Notation

The notation used in the diagram is that the arrow goes from

- the dependent concept

to

- the concept being used.

There will be a number of different types of relationships between concepts but there are three types used in the planning diagram that will be seen in the following sections.

- Where one concept requires the use of another concept

- Where one concept has an optional use for another concept

- Where one concept is a specialisation of another concept

6.3.3 Positioning Concepts on the IIM

While all the implications of using Application Modules within STEP are not understood, it is believed that the lower layer AMs and the Common Resources should map onto the IIM.

For the standard to be consistent and to allow reuse of Application Modules these lower layer AMs (and Common Resources) must be positioned or scoped within the overall structure of the IIM and the LCA.

There will also be basic relationships that link the concepts together: -

- Some of these will be fundamental truths; for example a product can be categorised in more than one way

- Others will be design decisions; for example, product shape could be represented by a geometric model

(it could also be represented by a drawing, and there are alternative geometric models).

The following diagram describes how the identification of various items could be modelled.
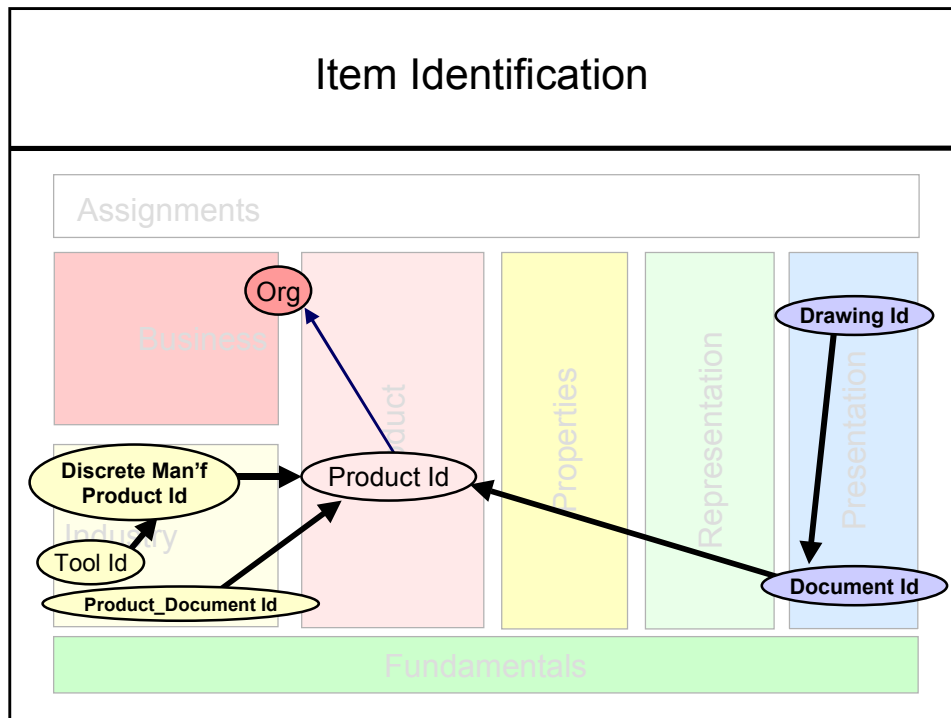
Figure 40 - Item Identification

Product ID is defined to cover the identification of any generic thing, item or **Product**. **Product ID** applies to any type of Product.

Discrete Manufactured Product ID: apply to products that are being manufactured and can be identified by a part number. This is, therefore, a product or industry specific concept.

Tool ID: within the Produce Facility a manufacturing tool name or number will identify tools, this is industry specific. Since this is still a product, it can use **Product ID**.

Document: this is a presentation of information in a human readable form. Documents can be used to present virtually any information and hence it uses **Product ID**. This does not preclude the possibility of other relationships between documents and products that define the product information that can be presented in a document. Indeed you would expect this in any PDM schema. It is also true that documents often are part of a delivered product, for instance the operators or owners manual supplied with a product. There may be a need for two concepts covering **Document**, **Product_Document** and **Document.**

Uniqueness of Identification: Identification of an item needs to be unique, there are a number of ways to satisfy this requirement. One could enforce a world-wide naming convention, however this is only practical for certain things like standards. It is not practical for all products. Since naming conventions are usually unique within an organisation the **Product ID** uses the **Org** concept. **Product ID** only has to be unique within Organisation.

6.3.4 A Backbone of Concepts

The following diagram outlines how a number of the core concepts relate to each other.

It is believed that these concepts will be defined in Application Modules, using or extending the Common

Resources and some subset of them will appear in most if not all Application Protocols. This core of concepts would therefore form a **Backbone** underlying Product Model Data and provide a minimum level of interoperability between Application Protocols.

It is believed that these Backbone concepts can be defined so that they are applicable to most, if not all, industries.
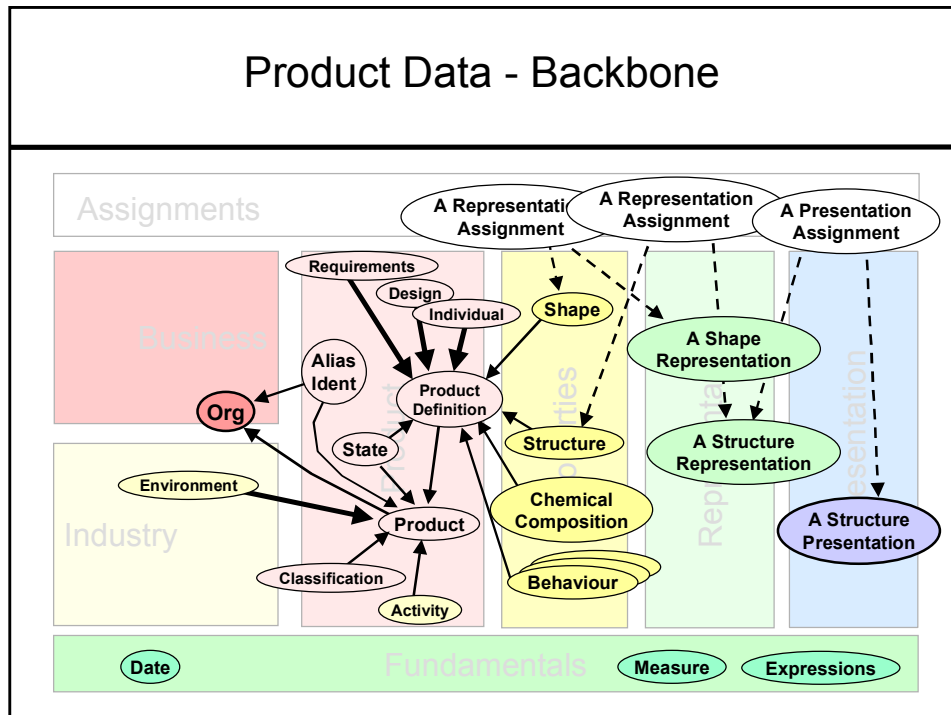
Figure 41 - Product Data Backbone

The diagram is centred on the concept of a **Product**. It shows that

- Any thing or **product** can have a definition (**product definition**)

- **Definitions** define the **properties** of the product

- The **properties** can be many and varied. The ones shown are **shape, chemical composition, structure** and **behaviour**, which is used as generic term for the various types of behaviour.

- **State** allows the condition of the **Product** to be identified. A **Product** and its behaviour or **Properties** may well change depending on the **State** of the **Product**. For instance, the **Shape** of a parachute is quite different when it is packed compared to when it is being used. Its aerodynamic properties are also different in the two states.

- The **environment** that a **product** is subjected to is also treated as a **product** and can have a **definition** and **properties**. The **environment** is the collection of conditions (e.g. temperature, pressure, etc.) to which a product is subject, and hence, the conditions at which the behaviour of a product exists. Some **products**, such as a jet engine, may have a major affect on the properties of its **environment**. A jet engine creates thrust by increasing the velocity of the air passing through it. This **environment** has properties, chemical composition, temperature, pressure, and velocity.

- **Properties** such as **Shape** (or **Structure**) can be represented in alternative ways. This diagram shows **Shape** being linked to a **Shape Representation**. This could be some geometric definition. Note the way it is linked. Neither the **representation** nor the **shape** concepts actually know the other exists.

Hence, a third concept links these two together. In effect, this is a design decision. Any industry deciding to exchange the shape of products would need to agree the actual representation to be used and if a geometric one is chosen, what class of geometric definition (wireframe, surface, solid etc).

- Other **Properties** (shown as Behaviour) will have alternative methods of representation.

- **Presentation**. Some industries need to exchange definitions of how to display or present information. For instance, a geometry representation may be linked to a **Presentation** module. In this example, it may define how lines, surfaces etc are to be displayed. The **Presentation** is linked to the **representation** by an assignment because there may be alternate options.

- **Definition** of a **Product** can be about the **requirements** for a product, the **design** of a product, or about an **individual** product. In the Life Cycle Activities there are two major information flows that are created: Product Design, which is the design of a Product that could be made and Individual product, which is information about a Product that has been produced.

- The concepts of **Product Requirements, Design** and **Individual** can also be used when describing the **Environment** in which the **Product** is operating.

- The identification of a **Product** is only unique within an **Organisation**.

- An **activity** that is carried out will either create or use products or product data in some way. These activities define relationships between product data. For instance the operation of a machine tool relates the tool to the part, both of which change **state**.

6.3.5 Relating Subjects to the Backbone

This section describes how various subjects can be mapped onto the IIM and proposes how they fit into the Backbone.

6.3.5.1 Industry Specific
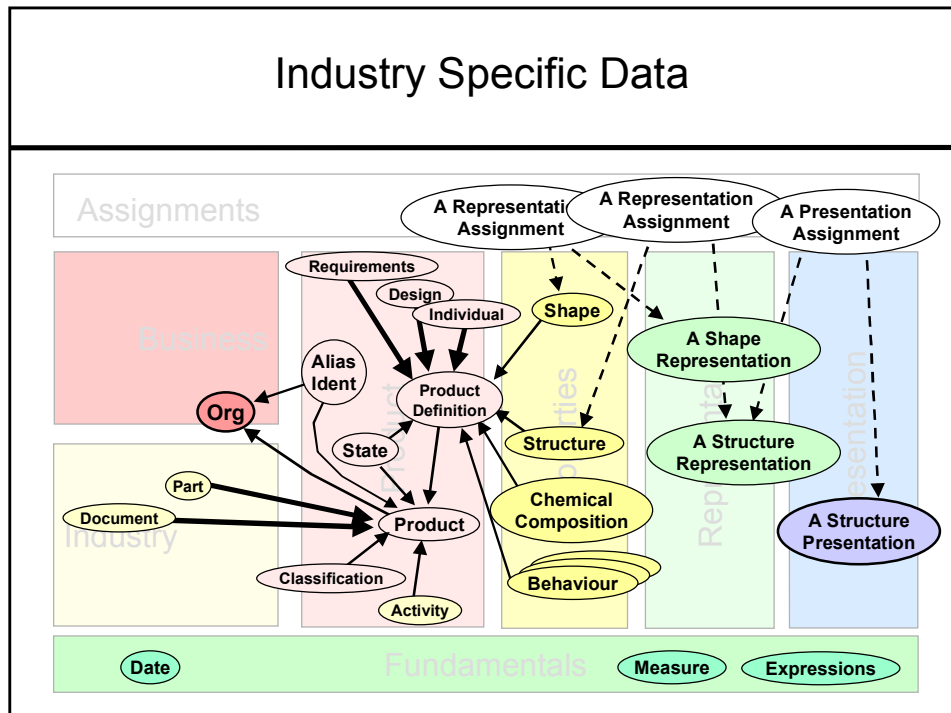
Figure 42 - Industry Specific Data

Industry specific data should fall into two categories

- Concepts that refine the product concept in some way - these fit into the Industry category of the IIM and into the backbone as shown on the diagram above.

- Specific types of Property and Representations of those properties - even if these are only used for a single industry/product type then they still fit into the IIM in the Representation and Presentation categories. They are then available for other industries should they ever be required.

6.3.5.2 Materials

The current materials schema within STEP covers the properties or behaviour of a 'Material'. It is recognised that Material properties are also properties of a product and that all 'engineering materials' are products. 'Material' does not have a separate existence. Material properties are characteristics of a product just as its shape is.

Typical 'Material Properties' are: -

- Strength
- Hardness
- Fracture toughness

The Property values have to be associated with the conditions under which they are valid, i.e. State.

As testing samples of material often produces the values, the confidence in the values can vary; hence values will have quantitative and qualitative measures.

The properties may be represented by a number of different forms including

- tabular data of properties against State

- mathematical models

Having ascertained the properties of a material type the Design process will use this information to predict the likely behaviour (properties) of a product manufactured from that material type.

The following diagram puts some of these concepts into context.
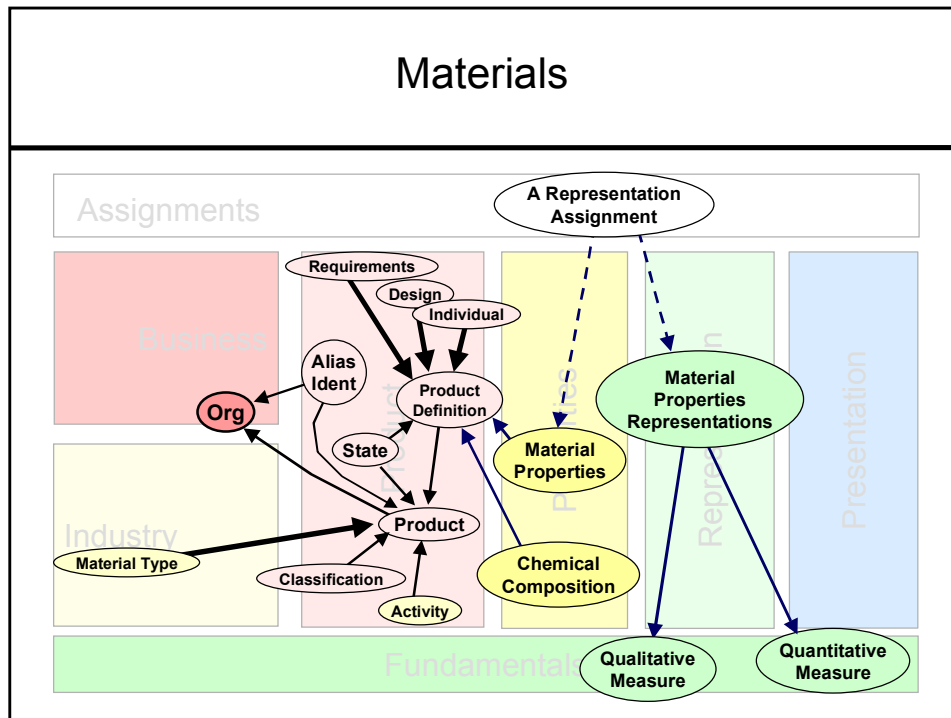
Figure 43 - Materials

6.3.5.3 Engineering Analysis

Engineering Analysis is the process of predicting the behaviour of a product and its environment. It utilises many different numerical techniques to model the laws of physics and to solve those equations.

The types of behaviour that will be predicted are numerous and include Acoustics, Aerodynamics, Costs, Dynamics, Electrical and Mechanical Behaviour, Fatigue, Fluid Mechanics, Fracture, Fuel Efficiency, Heat Transfer, Hydraulics, Kinematics, Optics, Producibility, Stress, Structures, Thermodynamics, and Vibrations.

The analysis will use a representation of both the product and its environment and use a mathematical model to predict the behaviour of a set of the above properties, and hence a set of attribute values, temperature, pressure, changed shape of product, stress, etc. Most of these parameters are continuous functions that will vary by **spatial position**.

These concepts are illustrated in the following diagram.
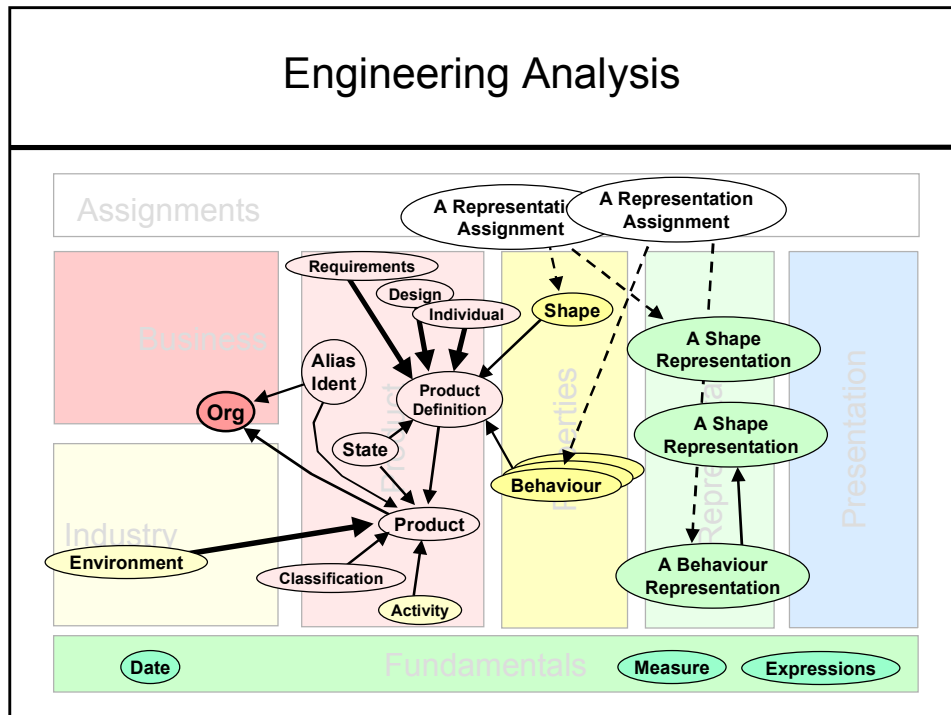
Figure 44 - Engineering Analysis

6.3.5.4 Relationship between Engineering Analysis and Materials

At some point in the Engineering Analysis process, the properties of the product will be predicted. These properties are, in fact, very similar, if not identical, to those considered within the Material property world. The manner in which the values where arrived at may well be different and hence the Representation may need to be different.

6.3.5.5 Other standards

Most industries exchange information about the properties or behaviour of a product in terms of attribute values. There are some industries that exchange this information in the form of a computer model that will be used to simulate the product behaviour when given the environment.

It is an open question as to whether STEP should address this second method but it should at least allow this type of information to be linked into the STEP model.

6.3.5.6 BLOBs and Files

There will be occasions where data is NOT held in a STEP structure and STEP needs to be able to at least reference the information. This information could either be held in a **digital** format or as a **hardcopy**. If the information is held digitally, then it would also be possible for STEP to include the information within a STEP exchange file.

Examples of this are: -

- Documents are held in some proprietary format

- Where the shape of a product is defined by a hardcopy drawing

- Where the behaviour of a product is predicted by the use of computer software model

To handle this requirement two concepts would be required

- **BLOB - a binary large object**, this is a digital set of information in a NON STEP format with identification of its format. This would be a representation that could be assigned to a particular property to enable the exchange of the object itself.

- **External object ID** - this would be the identification of either a digital file or a hardcopy file when only the identification needs to be exchanged.
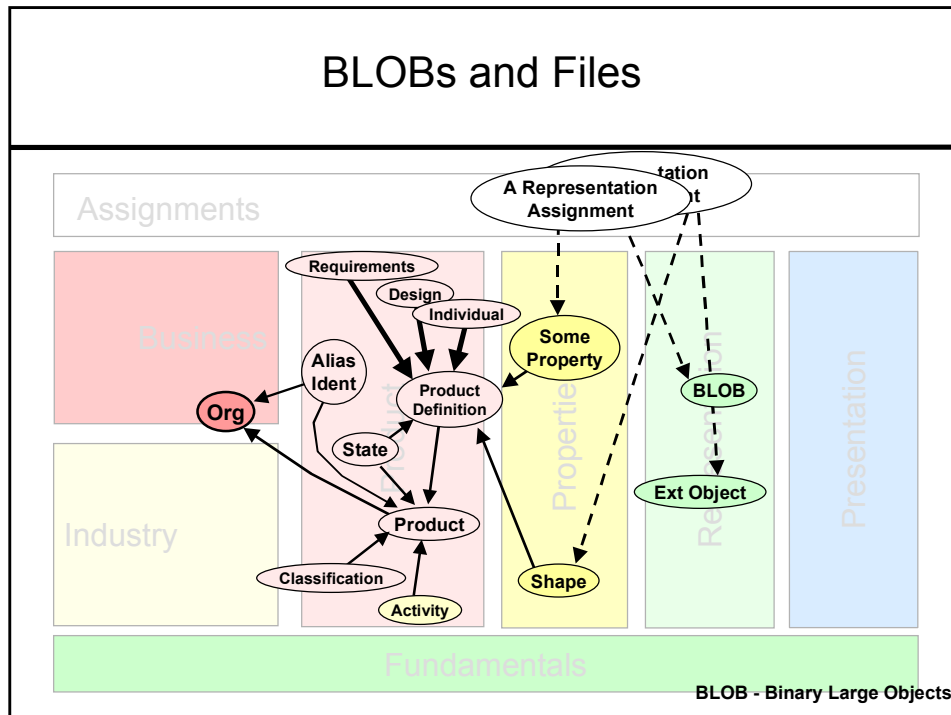
Figure 45 - BLOBs and Files

Note: STEP contains Implementation Methods (Part 20 series) that map the Information Models to an Implementation Method, such as a Part 21 file. These concepts are different from the above but would be used to map either the BLOB or the External File ID to, say, a Part 21 file.

6.3.5.7 Logistics

Logistics is the science of the movement, supplying, maintenance and support of a Product. To carry out the support process, there is a requirement to have various types of information available: -

- The individual product that is to be maintained, for instance its configuration.

- The configurations that are allowed to be produced, i.e. the Product Designs.

- The facilities and their capabilities available within the Support Facility (the means for the Support process) to carry out the support process. This would normally be the individual Support Facility but where new facilities are being planned, then this could be the design of the Support Facility.

- To carry out the logistics process, the location of real items in the world is required.

- The date and time

    - where a product is located

- when a new configuration applies

In another section, it was shown that the same general information model should support the Capability of the Support Facility. To support this some extensions to the Backbone will be required: -

- To describe the capabilities of the Support Facility a range of new Properties will be required; in the following diagram these are indicated by the group of properties shown as "Behaviour".

- To provide an industry understanding of what facilities are available, some industry concepts will need to specialise concepts such as Product.

- To provide a Location property that allows the position in the world of a real object to be defined.
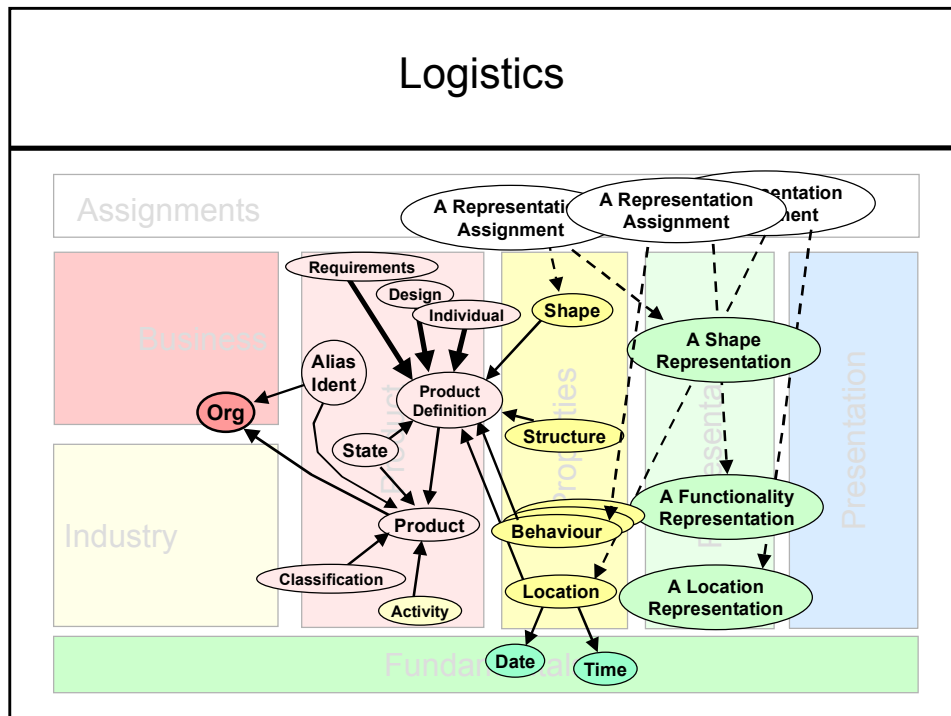
Figure 46 - Logistics

6.3.5.8 Product Data Management

PDM, Configuration Management, and Change Management concepts will support the majority of the Data Backbone. The scope of these is shown in the diagram below. They include the concepts of

- Products having definitions that describe the structure and properties of the product

- Authorisation and change management of these definitions

- Certain products/items being configuration controlled by industry

- The incorporation of parts into assemblies (Effectivity) being controlled

- Product data being created as a result of a project which is subject to a contract and security considerations
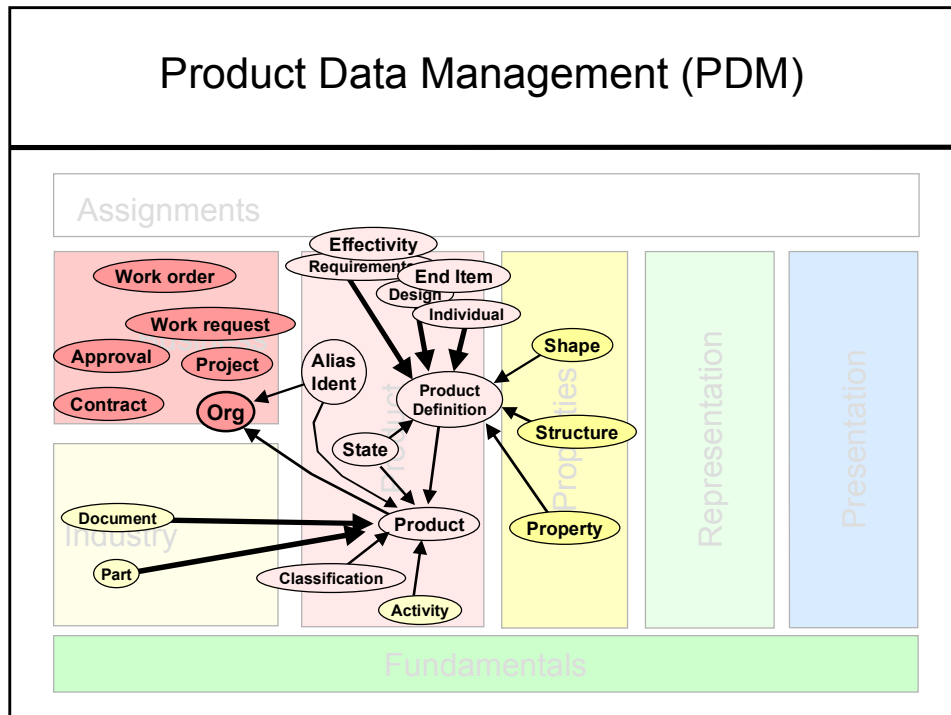
Figure 47 - Product Data Management

6.3.5.9 Product Requirements

Requirements entering the Life Cycle Activities can specify values required by the customer for any of the information flows within the rest of the process.

For instance, the Requirements could define: -

- Properties of the product being designed

- Requirements on the operation of the life cycle processes, how long the design should take, how easily the product can be maintained.

- How much the customer is willing to pay for the product.

- The number of products required.

Where the Requirements specify the values wanted for the individual product then the following extension to the Backbone is required.

Requirement Assignment

Typical requirements are specified in statements such as

- the thrust of the engine must be greater than 130,000 newtons.

- the mass of the product must be less than 250 kilograms.

- the aircraft must transport between 200 passengers and 250 passengers for at least 3,500 kilometres

- the resistor must handle an electrical current of up to 2.5 amperes

To handle these statements the **Representation Assignment** needs to be refined to allow a more complex relationship between the **property** and its **representation**. This **Requirement Assignment** must enable the relationships of the form

- **equal to**
- **less than**
- **greater than**
- **up to**
- **at least**
- **within a range** (this would assign two representations to the property)
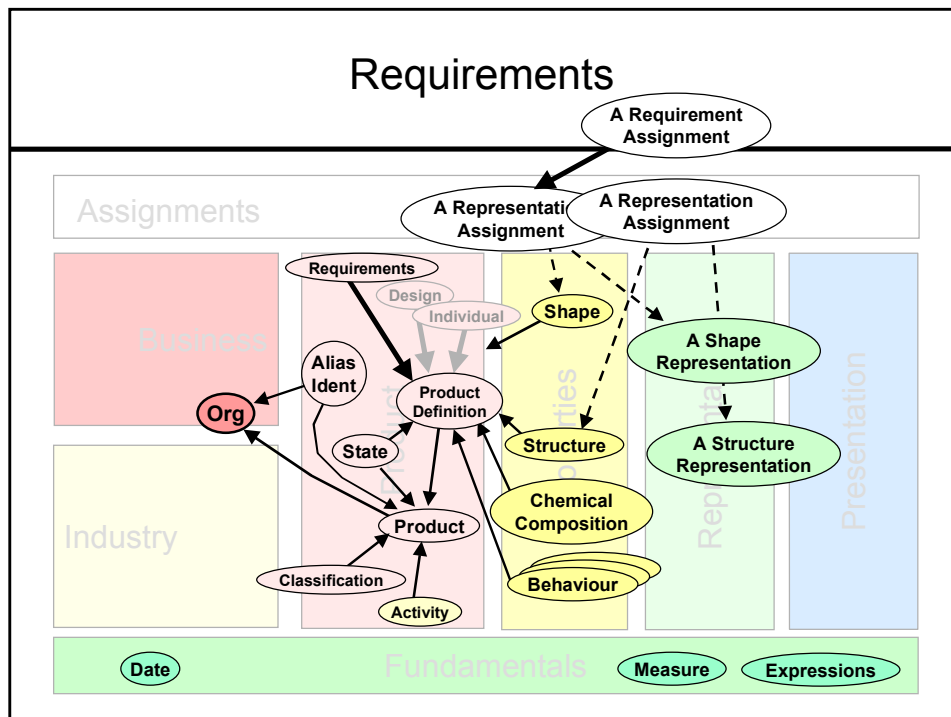
Figure 48 - Requirements

6.3.5.10   Validation of Data

For some types of representation, it may be desirable when exchanging information to include additional data against which data translations can be validated. This is particularly true for complex representations such as 3D solid geometry where different calculation tolerances in CAD systems can affect the success of a translation.

Validation
- Representation Properties
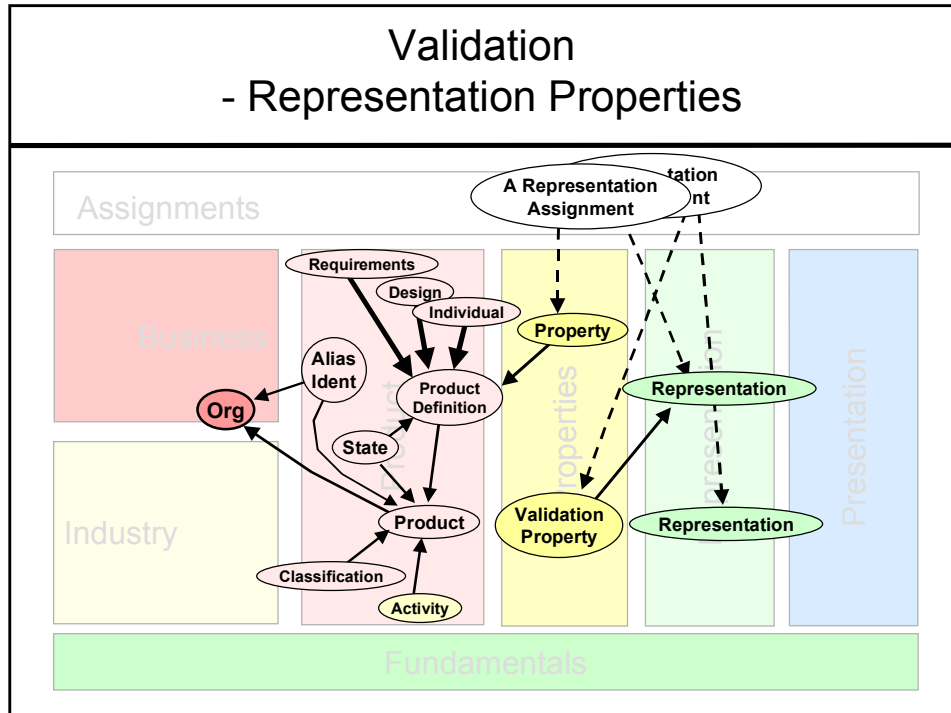
Figure 49 - Validation

For instance, when exchanging geometric solid models, the properties of the solid can be exchanged and these can be checked to validate that any geometric conversions have been carried out correctly. It is important to note that the properties such as the volume of the geometry solid can be quite different from the intended volume of the actual product. This is because the geometry may only be an approximate representation of the product shape. It is important to be precise about the different in these properties.

This data does NOT describe the product. It describes a property of a representation; which in turn is a representation of a property of the product. Hence they should be specified as Properties of the Representation. (They in turn have their own representation).

7   STEP AP Framework

When companies wish to exchange information they will need to select the most suitable AP to use. This section proposes a number of requirements on AP developments and a number of ways to categorise Application Protocols such that users will be able to more easily select the appropriate AP. A common understanding of the scope and applicability of the APs should also improve the consistency of APs as they are developed.

It is understood that any categorisation should be complete and unambiguous. As such, any suitable item that is being categorised should preferably fit in one and only one category. While attempts have been made to achieve this, not all of the categorisation methods are that rigorous. As long as the reader is willing to cope with some level of uncertainty, the proposed categorisation methods should be useful in achieving the purpose defined above.

The following methods to categorise APs, or show the commonality or help identify missing items, have been defined as follows: -

Industry Sector - see section 4.1, "Industrial Structure", page 16. This provides a set of Industry Sectors or product types to which an AP may be applicable. It is hoped that APs will in the future be applicable to as wide a cross section of industries as possible and that many APs will cover most industries.

Disciplines - see section 4.2, "Professional Discipline", page 18 . This provides a set of Professional Disciplines to which an AP may be applicable.

Life Cycle Activity - see section 4.3, "Life Cycle Activities ", page 19. This provides a high level set of activities (or processes) for which an AP may be applicable.

Information flow on LCA - see section 6.1, "Types of Industrial Data and Relationships between them.", page 45. This section looked at the types of information in the Life Cycle Activities Reference Model and shows that there are four distinct types of information. APs can be classified by which of these types they support. See "Table 3 - Activity and Type of Industrial Data", page 85.

"Annex A - Dependency Diagrams", page 77, are examples of the diagrams that can be used to identify both missing concepts within APs and AMs as well as commonalties between them.

"Annex B - Tables", 2 to 4 are examples of tables that could be used to categorise APs. "Table 2 - Industry versus Business Functions", page 81, uses the life cycle and business activities with the industry sector to categorise APs. This categorisation method has been used to categorise the current Application Protocols and is incorporated in a set of web pages known as the "AP Units of Functionality web". This can be accessed from the web site http://wg10step.aticorp.org/. This table shows much of the commonality of coverage of the current APs. This table provides an initial very high level analysis of the harmonisation required between APs

7.1   Requirements

This section outlines industry requirements that, if followed, will improve the support of individual APs.

- APs should attempt to be applicable to as many industries as possible.

- APs should be categorised, using the above methods, as early as possible during their development.

- The development of APs can be shortened by the flexible, rigorous reuse, and / or customising of existing APs or AMs, based on a rigorous set of Common Resources.

- APs (and AMs) that are developed to cover Configuration Management should have a consistent "Item Identifier" for the Product/Industry for which they are applicable.

- Each AP or Conformance Class should have a well defined scope

- It should apply to a defined industry (or preferably be common across industry) and should use the terminology of that industry.

- It should be applicable to one of the Life Cycle activities and at least one of the information flows or some decomposition of these.

- APs aimed at exchanging or sharing data up or down the supply chain should use terminology common to all of the industries involved.

- If an industry specific AP is being created it should be consistent with any existing cross industry APs.

8 STEP AM Framework

The STEP integrated resources define a generic information model for product information. They are not sufficient to support the information requirements of an application without the addition of application specific constraints, relationships and attributes.

ISO 10303 defines application protocols in which the integrated resources are interpreted to meet the product information requirements of specific applications. The interpretation is achieved by selecting appropriate resource constructs and refining their meaning, by specifying any appropriate constraints, relationships, and attributes. This interpretation results in an application interpreted model.

Initially, the application interpreted model was documented as part of an application protocol. Wherever a resource construct is used to represent the same information requirement in different application protocols, the intention is that the same interpretation of the resource construct is used. The scope and information requirements of the application are specified in the terminology of the application.

The aim of application modules is to document both the information requirement and the application interpreted model so that it can be used by any application protocol that requires that functionality.

The concept of a Backbone of Concepts that should be true for most industries has been described under "6.3 Data Backbone", page 56. The assumption behind this is that different industries are actually very similar once the different terminologies have been understood. If these similarities can be identified and built upon then STEP will be more widely accepted and more quickly developed and implemented.

In particular, if application modules are created (supported by appropriate extensions to the IRs) that support the concept of a data backbone and that these application modules form the core of new application protocols then the interoperability of APs will be vastly improved.

8.1 Testing the Backbone for Different Product Types

To achieve a Backbone of STEP Application Modules that support a range of industries, we need to test the concepts against a suitable range of product types. In section 4.1, "Industrial Structure", page 16 a view of the types of industry that need to be considered is presented.

This provides a useful list of industry types and hence product types to test the backbone against. In addition to this list, we need to test that these concepts also support the complete life cycle of the product as well as the facilities that create the products. The backbone should support

- the Design, Produce, Operate, Support, and Dispose stages for both the product and facilities.

8.2 Extending Property Types and their Representations

Probably the main area of STEP that will continually be extended is that of Property types and their Representation. As new products are developed new properties and their representations will be needed.

Some of these properties and representations will apply to a wide range of products and some will be specific to certain industries. (Generic versus industry specific).
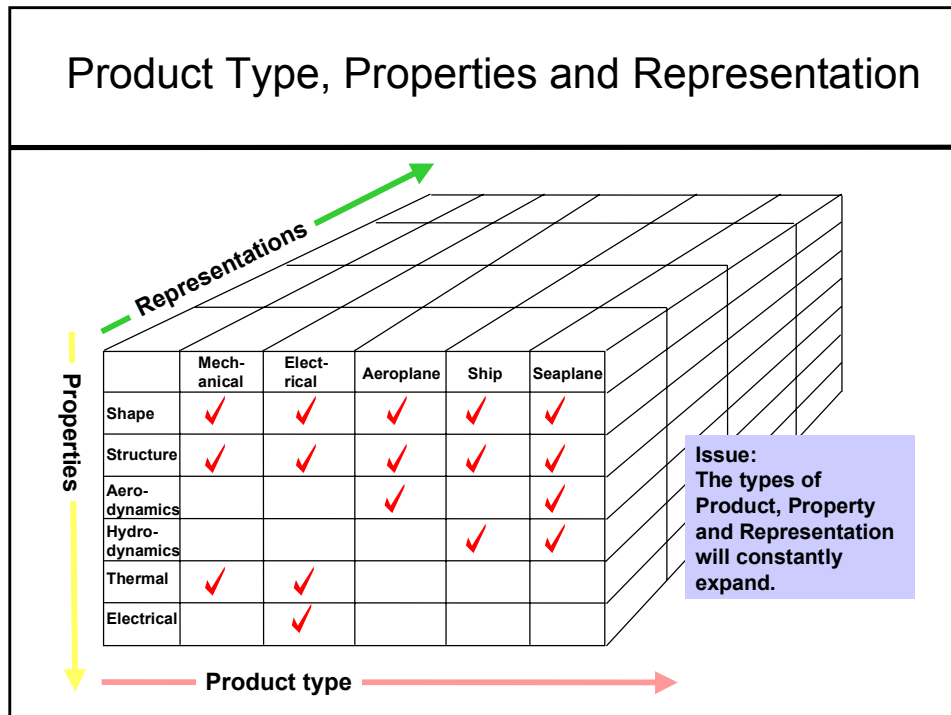
Figure 50 - Product Type, Properties and Representations

8.3 Classification of Modules

As the number of Application Modules grows, it will become important to be able to find what AMs exist and what concepts they cover. To help enable this, there have been proposals to have a Catalogue of Application Modules.

An aspect of any Catalogue will be the methods for finding the modules of interest. It is proposed that a number of methods for categorising modules should be used to help the user find appropriate modules. This section proposes various ways of categorising industrial data. These categories could be used within a module catalogue to provide a user-friendly method for selecting modules that are of interest.

The following categorisation methods are proposed for the modules:

Industry Sector - see section 4.1, "Industrial Structure", page 16. This provides a set of Industry Sectors into which items can be categorised. There will be high level Application Modules that could be categorised against Industry sector. The lower level AMs are likely to apply across most industries.

Disciplines - see section 4.2, "Professional Discipline", page 18. This provides a set of Professional Disciplines to which an AM may be applicable.

Industrial Information Model - see section 6.3.1, "Industrial Information Model", page 57. This model was used to help describe the concept of a data backbone. The model can be used to categorise the lower level (fundamental/foundation) modules.

9 STEP CR Framework

To be defined.

10 Annex A - Dependency Diagrams

These **AP Dependency Diagrams** are divided into three sections (vertically). The centre portion indicates the concepts required for the particular product type and its design, produce and support activities. The top and bottom portions indicate the information passing between a company and either its customer (top) or suppliers (bottom).

It should be noted that the production of Aircraft, Ships and Process Plants would require the concepts for Mechanical Products (Figure 51). The dependency diagrams for these three products are all very similar, showing the commonality between industries. A single diagram covering all these produces could be produced.

Fig-A-1-1 Dependencies of APs for Mechanical Products
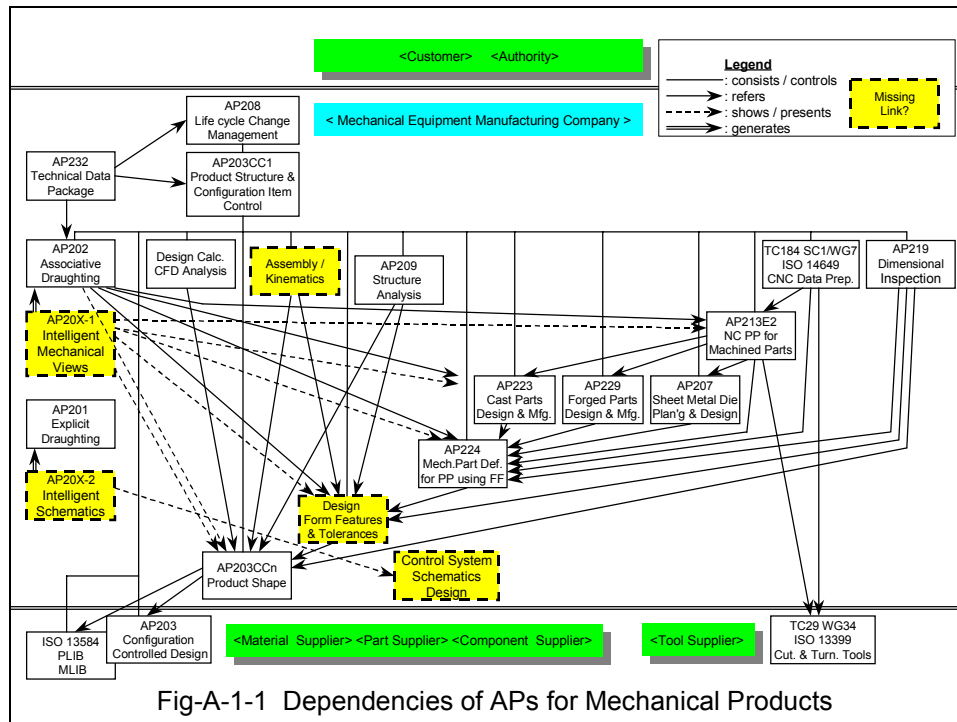
Figure 51 - Dependencies of APs for Mechanical Products

Fig-A-1-2 Dependencies of APs for Aircraft Assembly
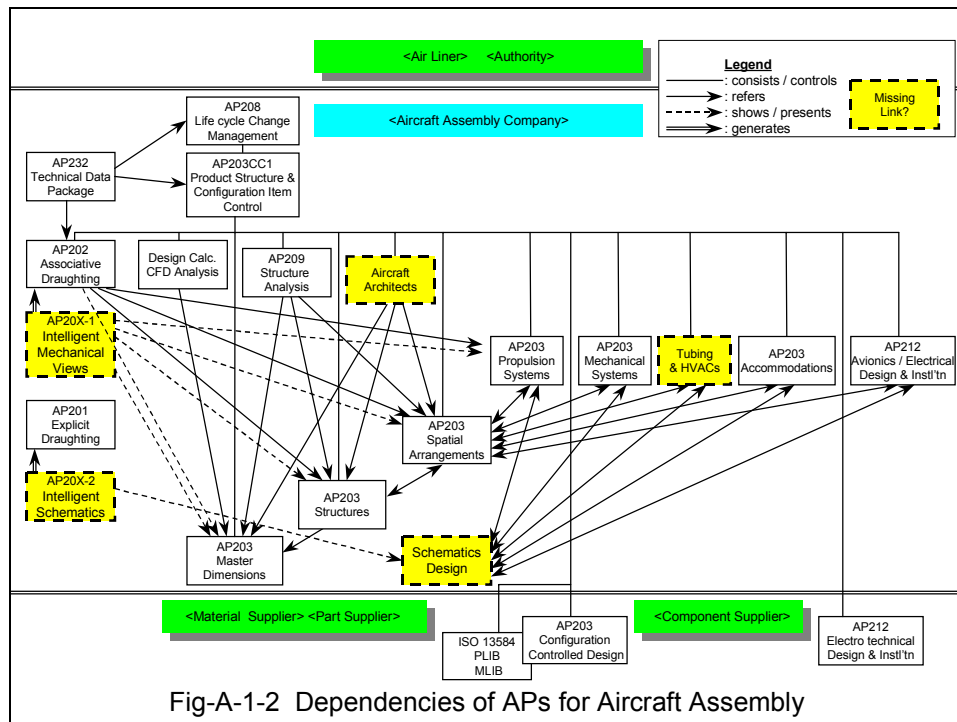
Figure 52 - Dependencies of APs for Aircraft Assembly

Fig-A-1-4 Dependencies of APs for Shipbuilding
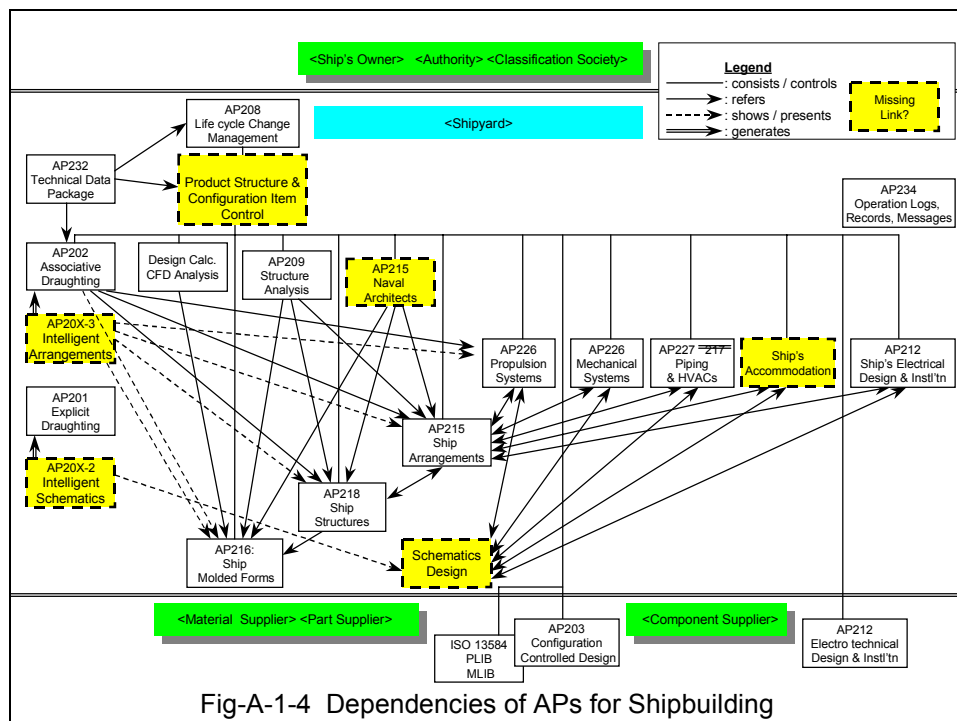
Figure 53 - Dependencies of APs for Shipbuilding
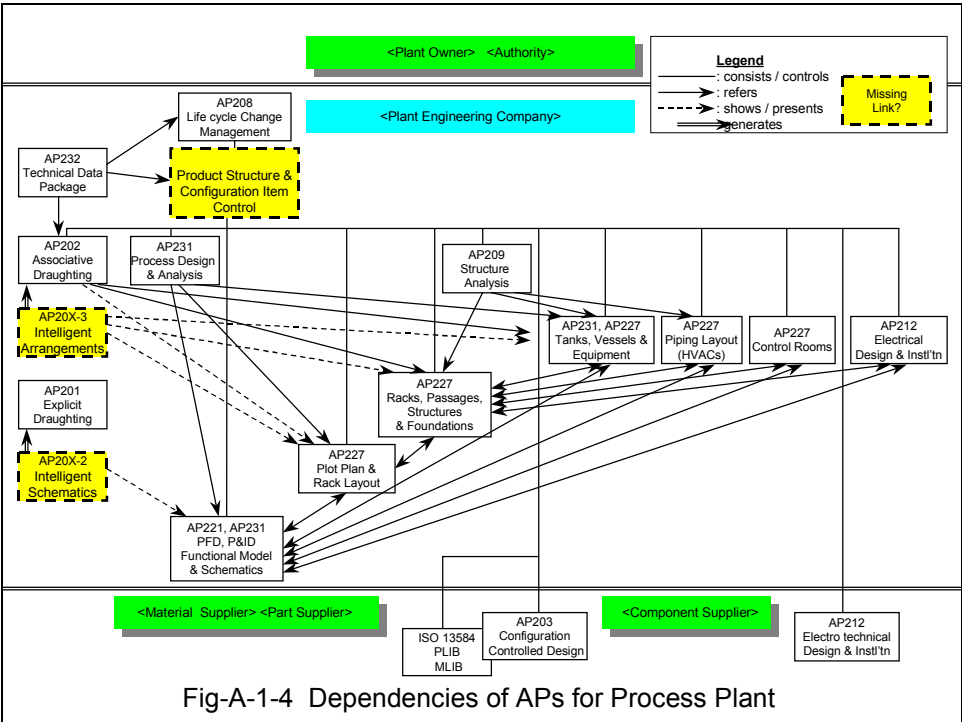
Fig-A-1-4 Dependencies of APs for Process Plant

Figure 54 - Dependencies of APs for Process Plant

Fig-A-2.1   Dependencies of IRs for Mechanical Parts / Assembly

Figure 55 - Dependencies of IRs for Mechanical Parts/Assembly

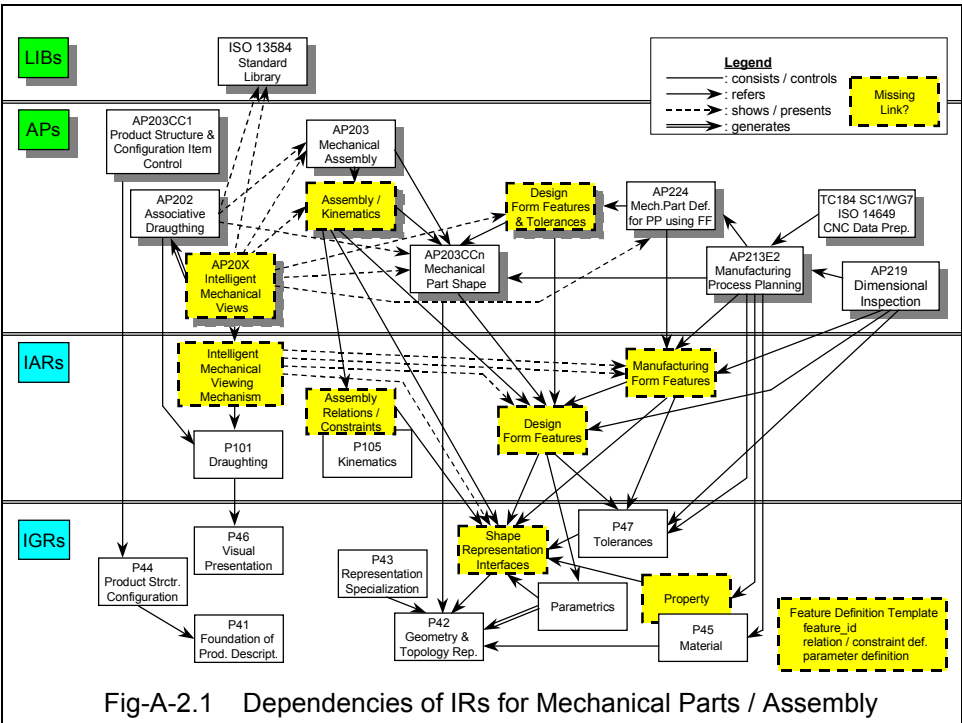Fig-A-2-2   Dependencies of IRs for Schematics Design
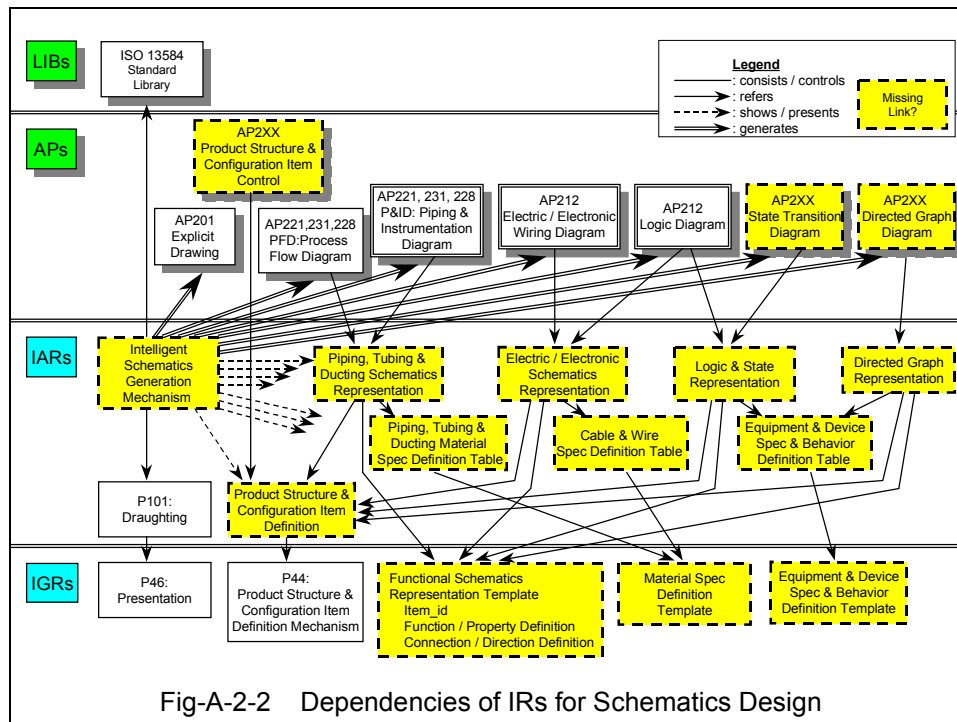
Figure 56 - Dependencies of IRs for Schematics Design

Fig-A-2-3   Dependencies of IRs for Spatial Arrangements
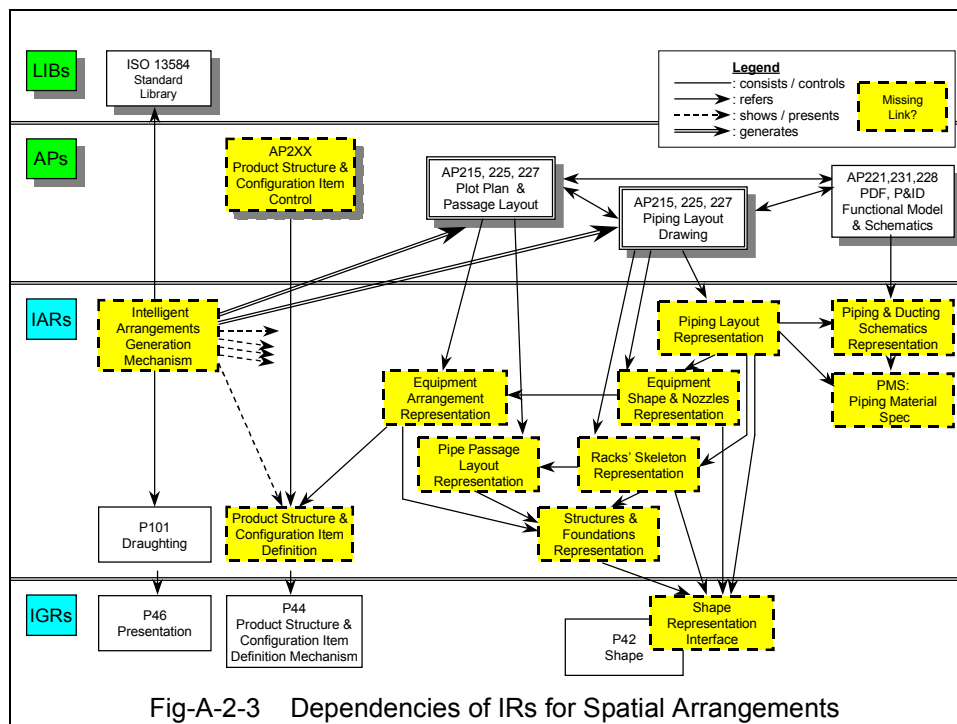
Figure 57 - Dependencies of IRs for Spatial Arrangements

11 Annex B - Tables

Table 1 - Professional Discipline versus Industry (or Product)

Table - Professional Discipline versus Industry (or Product)

Professional Discipline	Process Industry		Parts / Component Mfg. Ind.			Large Scale Assembly Industry					
Industry and/or Product	Raw Material Process Industry	Chemical Industry	Parts Mfg. Industry	Machinery	Electric / Electronic Devices	Automobile	Aircraft & Space Craft	Ship	Building & Construction	Process Plant	Electric / Communicat'n Systems
Geological Engineering	P								W	W	
Mining Engineering	P										
Metallurgical Engineering	P	P	W	W	W	W	W	W	W	W	
Ceramics Engineering	P	P	W	W	W					W	
Petroleum Engineering	P	P								W	
Chemical Engineering	P	P								W	
Plastics and/or Polymer Chemical Engineering	P	P								W	
Mechanical Engineering	W		P	P	W	W	W	W	W	W	
Electrical Engineering-1/2											
Electric Machinery Engineering	W	W		W	P	W	W	W	W	W	W
Electronics Engineering			P		P	W	W	W	W	W	P
Computer Engineering	W	W			P	W	W	W	W	W	P
Instrumentation and Control Engineering	W	W	P	W	P	W	W	W	W	W	W
Automotive Engineering	W					P					
Road & Railway Engineering	W					P			W		
Aeronautics							P				
Astronautics							P				
Shipbuilding Engineering and/or Naval Architects	W							P			
Ocean Engineering	P							P			
Architects	W								P		
Civil Engineering	W								P	W	
Road and Railway Engineering	W					W			P		
Transportation Engineering	W					W	W	W	P		
Process Plant Engineering	W									P	
Electrical Engineering-2/2											
Communication Systems Engineering	W	W			W	W	W	W	W	W	P
Power Systems Engineering	W	W			W	W	W	W	W	W	P
Systems Engineering	W	W	W	W	W	W	W	W	W	W	W
Quality Assurance Engineering	W	W	W	W	W	W	W	W	W	W	W
Environmental Engineering	W	W	W	W	W	W	W	W	W	W	W
Safety Engineering	W	W	W	W	W	W	W	W	W	W	W
Industrial Engineering	W	W	W	W	W	W	W	W	W	W	W
Information Engineering	W	W	W	W	W	W	W	W	W	W	W
Engineering Analysis	W	W	W	W	W	W	W	W	W	W	W

Legend :   P: Main Product of the Discipline
W: the Discipline is working for that Industry

Table 2 - Industry versus Business Functions (1/3)

	Business Functions	Cross Common APs	Process Industry		Parts / Component Mfg. Industry				Large Scale Assembly Industry				Electric/ Communicat'n Systems
	Design & Engineering Activities — *Output of Activity*		Raw Material Process Industry	Chemical Industry	Parts Mfg. Industry	Machinery	Electric/ Electronic Devices	Automobile	Aircraft & Space Craft	Ship	Building & Construction	Process Plant	
2	**Configuration Management**												
2.1	Change Management	208	x	x	x	X	X	X	X	x	x	x	X
2.2	Requirements Management	X	x	x	x	X	X	X	X	x	x	x	X
2.3	Configuration Item Control	X	x	x	x	X	X	X	X	x	x	x	X
3	**Design & Engineering**												
3.0	Product Data Management & Documentation												
3.0.1	Product Data Management	232	=	=	=	=	=	=	=	=	=	=	=
3.0.2	Documentation	SGML	=	=	=	=	=	=	=	=	=	=	=
3.0.3	Draughting	201,202	=	=	=	=	=	=	=	=	=	=	=
3.1	Conceptual Design												
3.1.1	Systems Engineering Model Definition	233	=	=	=	=	=	=	=	=	=	=	=
3.1.2	Systems Specification Definition	X	x	x	x	x	x	X	X	X	x	x	X
3.1.3	Components & Specifications Breakdown	X	x	x	x	X	X	X	X	X	x	X	X
3.2	Performance & Functional Design												
3.2.1	External Surface Design												
3.2.1.1	*Fluid Dynamic Surface*	X						X	X	X			
3.2.1.2	*Arbitrary Free Form Surface*	X		x		x	x	X	X	x	x	x	x
3.2.1.3	*Others*	X	x	x	x	X	x	x		x	x	x	x
3.2.2	Spatial Arrangements	X	x	x	x	X	x	X	X	X	x	x	X
3.2.3	Schematics Design												
3.2.3.1	*Process Plant System*	X	x	x								X	X
3.2.3.2	*Mechanical System*	X	x	x		x		x	x	x	x	X	X
3.2.3.3	*HVAC System*	X	x	x						x	x	X	X
3.2.3.4	*Electro-Technical System*	212	x	x	x		X	x	x	x	x	x	X
3.2.3.5	*Instrumentation & Control System*	212	x	x	x	x	X	x	x	x	x	X	X
3.2.4	Component Specification Definition												
3.2.4.1	*Machinery*	X	x	x	x	X		X	X	X	x	X	X
3.2.4.2	*Electro-Technical Equipment*	X	x	x	x	X	X	X	X	X	x	X	X
3.3	Production Engineering												
3.3.1	Mechanical Assembly/ Parts Design for Manufacturing												
3.3.1.1	Mechanical Parts												
3.3.1.1.1	*Shape*	203-n			x	x	x	x	X				
3.3.1.1.2	*Design Form Features*	X			x	X	x	X	X				
3.3.1.1.3	*Tolerances*	219			x	X	x	X	X				
3.3.1.1.4	*Mechanical Product Definition for Process Planning*	224			x	X	x	X	X				
3.3.1.1.5	*NC Process Planning & NC Data Preparation*	213			x	X		X	X				
3.3.1.2	Design & Mfg. for Cast Parts	223			x	X		X	X				
3.3.1.3	Design & Mfg. for Forged Parts	229			x	X		X	X				
3.3.1.4	Sheet Metals Manufacturing	X			x	X	x	X	X				
3.3.1.5	Welding	X			x	X	x	X	X				

Legend : x : Candidate Cross Industry Common AP and/or Representative Industry, = : ditto to the left cell,
PLIB : Parts Library, MLIB : Material Library, MCM : Muliti-Chip Module, SGML : SGML Family of Standards

X : Candidate AP,

Table 2 - Industry versus Business Functions (2/3)

Section	Business Functions	Cross Common APs	Raw Material Process Industry	Chemical Industry	Parts Mfg. Industry	Machinery	Electric/ Electronic Devices	Automobile	Aircraft & Space Craft	Ship	Building & Construction	Process Plant	Electric/ Communicat'n Systems
3	Design & Engineering <Continued>												
3.3	Production Engineering <Continued>												
3.3.1	Mechanical Assembly/ Parts Design for Manufacturing <Continued>												
3.3.1.6	Process Planning of Assembly	X				x	x	X	X	x	x	x	x
3.3.1.7	Dimensional Inspection	219			x	x	x	X	X	x	x	x	x
3.3.1.8	Measured Data	X			x	X	x	X	x	x	x	x	x
3.3.2	Electro-Mechanical Assembly & Components Design for Manufacturing	210,212			X		X						x
3.3.3	Printed Circuit Board Design for Manufacturing (incl. MCM)	210,220			X		X						
3.3.4	Foundations Design & Construction Engineering	X	x	x							x	x	x
3.3.5	Structure Design, & Fabrication & Construction Engineering												
3.3.5.1	External Surface Structure												
3.3.5.1.1	Monocoque Structure	X							X				
3.3.5.1.2	Others	X	x	x		x	x	x		x	x		
3.3.5.2	Inner Structure												
3.3.5.2.1	Plate/ Shell Structure	X	x	x		x	x	x	x	X	x	x	x
3.3.5.2.2	Frame/ Beam Structure	X	x	x		x	x	x	x	X	X	X	x
3.3.5.2.3	Others	X	x	x		X		x	x	X			X
3.3.5.3	Cable Suspension Structure	X	x	x				x	X	x	x	x	X
3.3.6	Equipment Installation Design & Engineering	X	x	x				x	x	x	x	x	x
3.3.7	Piping/ Ducting/ Cabling/ Racks & Supports Layout Design, Fabrication & Construction Engineering												
3.3.7.1	Piping & Tubing												
3.3.7.1.1	Piping on de-Cartesian Coordinate Space	X	x	x						x	x	x	x
3.3.7.1.2	Tubing	X				x		x	X	x			
3.3.7.2	Ducting (HVACS)	X	x	x		x	x	x	X	x	x	x	x
3.3.7.3	Cabling/ Wiring												
3.3.7.3.1	Cable Rack & Cable Installation	212	x	x						x	x		X
3.3.7.3.2	Wire Harness	212	x			x	X	x	x	x	x	x	X
3.3.7.4	Racks & Supports	X	x	x				x	x	x	x	x	x
3.4	Support Engineering												
3.4.0.1	Operations Manual	X				x	X	x	X	x	x	x	x
3.4.0.2	Repair & Overhaul Manual	X				x	X	x	X	x	x	x	x
3.4.0.3	Remote Monitoring					x	x	x	x	x	x	x	x
3.5	Recycle/ Disposal Engineering												
3.5.0.1	Recycle/ Disposal Manual	X	x	x	x	X	X	X	X	x	x	x	x

Legend : x : Candidate AP, X : Candidate Cross Industry Common AP and/or Representative Industry, = : ditto to the left cell, PLIB : Parts Library, MLIB : Material Library, MCM : Multi-Chip Module, SGML : SGML Family of Standards

Table 2 - Industry versus Business Functions (3/3)

Business Functions / Design & Engineering Activities / Output of Activity		Cross Industry Common APs	Process Industry		Parts / Component Mfg. Industry				Large Scale Assembly Industry				
			Raw Material Process Industry	Chemical Industry	Parts Mfg. Industry	Machinery	Electric/ Electronic Devices	Automobile	Aircraft & Space Craft	Ship	Building & Construction	Process Plant	Electric/ Communicat'n Systems
3.6	Engineering Analysis												
3.6.0.1	Systems Engineering Analysis	233	=	=	=	=	=	=	=	=	=	=	=
3.6.0.2	Heat & Mass Balance	X	X	X		X			=	X	X	X	=
3.6.0.3	Computational Fluid Dynamics	X	X	X		X		X	X	X	X	X	X
3.6.0.4	Naval Architects									X			
3.6.0.5	Aircraft Architects								X				
3.6.0.6	Structure Analysis	209	X	X	X	X	X	X	X	X	X	X	X
3.6.0.7	Thermal Analysis	X	X	X	X	X	X	X	X	X	X	X	
3.6.0.8	Kinematics	X	X	X		X	X	X	X	X			
3.6.0.9	State Transition Analysis	X	X	X	X	X	X	X	X	X	X	X	X
3.6.0.10	Logic Analysis	X			X		X					X	
3.6.0.11	FMECA	X	X	X	X	X	X	X	X	X	X	X	X
3.6.0.12	FTA	X	X	X	X	X	X	X	X	X	X	X	X
5	Production Control												
5.1	Long Term & Short Term Productions Planning	X	X	X	X	X	X	X	X	X	X	X	X
5.2	Facility Planning & Sourceing Plan	X	X	X	X	X	X	X	X	X	X	X	X
5.3	Material Requirements Planning	X	X	X	X	X	X	X	X			X	X
5.4	Production/ Procurements Order Release	X	X	X	X	X	X	X	X	X		X	X
5.5	Parts Manufacturing Shop Control & Operation	X			X	X	X	X	X	X			
5.6	Assembly Shop Control & Operation	X				X	X	X	X	X			
5.7	Site Construction	X									X	X	X
5.8	Commissioning	X									X	X	X
5.9	Inventry Control	X	X	X	X	X	X	X	X	X	X	X	X
6	Operations <Customer>	X	X	X				X	X	X	X	X	X
7	Product Support	X	X	X		X		X	X	X	X	X	X
8	Recycle/ Disposal	X	X	X	X	X	X	X	X	X	X	X	X

Legend : x : Candidate AP, X : Candidate Cross Industry Common AP and/or Representative Industry, = : ditto to the left cell,
PLIB : Parts Library, MLIB : Material Library, MCM : Muliti-Chip Module, SGML : SGML Family of Standards

Table 3 - Activity and Type of Industrial Data

	Types of Industrial Data			
Activity	Business Data	Product Requirement	Product Design	Individual product
Configuration Management				
Design				
Produce				
Operate				
Support				
Dispose				

Table 4 - Hierarchical AP Classification Structure

Class-5: APs for each Business Management Function

Layer-9: Business Management APs
Group-3: Recycle / Disposal Support & Control

Group-2: Products Support Control

Group-1: Productions / Operations Control

Class-4: APs for Product Life cycle, covering Configuration Management and multiple Design / Engineering Activities

Layer-8: Product Life cycle APs for Operators
Group-3: Transportation

Group-2: Plant Owners

Group-1: Infrastructure Providers

Layer-7: Product Life cycle APs for Large Scale Assembly Products
Group-3: Electric / Communications System

Group-2: Shipbuilding and AEC

Group-1: Vehicles and Crafts

Layer-6: Product Life cycle APs for Component Products

Class-3: APs for each Design / Engineering Activity

Layer-5: Design / Engineering APs specific for a Product
Group-4: Engineering Analysis (2/2)

Group-3: Foundations & Structure Design, Fabrication & Construction

Group-2: Spatial Arrangements (2/2)

Group-1: External Surface Design

Layer-4: Design / Engineering APs common for Products
Group-6: Engineering Analysis (1/2)

Group-5: Outfitting Design, Fabrication & Installation

Group-4: Electric / Electronic Equipment Design for Manufacturing

Group-3: Mechanical Assembly / Parts Design for Manufacturing

Group-2: Spatial Arrangements (1/2)

Group-1: Functional System Schematic Design

Class-2: APs common for Design / Engineering Activities

Layer-3: PLIB, MLIB Access APs

Layer-2: Product Data Management and Documentation APs
Group-2: Documentation & Draughting

Group-1: Product Data Management APs

Class-1: APs common for Business Functions

Layer-1: Configuration Management APs
Group-1: Configuration Management APs

Table 5 - Decomposition of Life Cycle Activities

1   Project Management

1.1   Work Breakdown Structure Definition

1.2   Contingency Planning & Control

1.3   Schedule Planning & Progress Control

1.4   Resource Planning & Allocation

1.5   Budgeting & Cost Control

1.6   Action Item Tracking

2   Configuration Management

2.1   Change Management

2.2   Requirements Management

2.3   Configuration Item Control

3   Design

3.1   Conceptual Design

3.2   Performance and Functional Design

3.2.1   External Surface Design

3.2.2   Spatial Arrangements

3.2.3   Functional System Schematic Design

3.2.4   Components Specification Definition

3.3   Production Engineering

3.3.1   Mechanical Assembly/ Parts Design for Manufacturing

3.3.2   Electro-Mechanical Assembly/ Parts Design for Manufacturing

3.3.3   Printed Circuit Board Design for Manufacturing (incl. MCM)

3.3.4   Foundations Design & Construction Engineering

3.3.5   Structure Design, & Fabrication & Construction Engineering

3.3.6   Equipment Installation Design & Engineering

3.3.7   Piping/ Ducting/ Cabling/ Racks & Supports Layout Design, & Fabrication & Construction Engineering

3.4   Support Engineering

3.5   Recycle / Disposal Engineering

3.6   Engineering Analysis

3.6.1   Heat & Mass Balance

3.6.2   Computational Fluid Dynamics

3.6.3   Naval Architects

3.6.4   Structure Analysis

3.6.5   Thermal Analysis

3.6.6   Kinematics

3.6.7   State Transition Analysis

3.6.8   Logic Analysis

4   Produce

4.1   Long Term & Short Term Productions Planning

4.2   Facility Planning & Sourceing Plan

Table 6 - Design Activities and their Objects

Design Activities and *Their Objects*

	Design / Activities / Design & Engineering Objects
3.0	Product Data Management & Documentation
3.0.1	Product Data Management
3.0.2	Documentation
3.0.3	Draughting
3.1	Conceptual Design
3.1.1	Systems Specification Definition
3.1.2	Components & Specifications Breakdown
3.2	Performance & Functional Design
3.2.1	External Surface Design
3.2.1.1	*Fluid Dynamics Surface*
3.2.1.2	*Arbitrary Free Form Surface*
3.2.1.3	*Others*
3.2.2	Spatial Arrangements
3.2.3	Functional System Schematic Design
3.2.3.1	*Process Plant System*
3.2.3.2	*Mechanical System*
3.2.3.3	*HVAC System*
3.2.3.4	*Electro-Technical System*
3.2.3.5	*Instrumentation & Control System*
3.2.4	Components Specification Definition
3.2.4.1	*Machinery*
3.2.4.2	*Electro-Technical Equipment*

	Design / Activities / Design & Engineering Objects
3.3	Production Engineering
3.3.1	Mechanical Assembly/ Parts Design for Manufacturing
3.3.1.1	*Mechanical Assembly/ Parts*
3.3.1.1.1	*Shape*
3.3.1.1.2	*Design Form Feature*
3.3.1.1.3	*Tolerances*
3.3.1.1.4	*Mechanical Product Definition*
3.3.1.1.5	*for Process Planning*
3.3.1.1.6	*NC Process Planning &*
3.3.1.1.7	*NC Data Preparation*
3.3.1.2	*Design & Mfg. for Cast Parts*
3.3.1.3	*Design & Mfg. for Forged Parts*
3.3.1.4	*Sheet Metals Manufacturing*
3.3.1.5	*Welding*
3.3.2	Electro-Mechanical Assembly & Components Design for Manufacturing
3.3.3	Printed Circuit Board Design for Manufacturing (incl. MCM)
3.3.4	Foundations Design & Construction Engineering
3.3.5	Structure Design, & Fabrication & Construction Engineering
3.3.5.1	*External Surface Structure*
3.3.5.1.1	*Monocoque Structure*
3.3.5.1.2	*Others*
3.3.5.2	*Inner Structure*
3.3.5.2.1	*Plate/ Shell Structure*
3.3.5.2.2	*Frame/ Beam Structure*
3.3.5.2.3	*Others*
3.3.5.3	*Cable Suspension Structure*
3.3.6	Equipment Installation Design & Engineering
3.3.7	Piping/ Ducting/ Cabling/ Racks & Supports Layout Design, Fabrication & Construction Engineering
3.3.7.1	*Piping & Tubing*
3.3.7.1.1	*Piping on de-Cartesian Coordinate Space*
3.3.7.1.2	*Tubing*
3.3.7.2	*Ducting (HVACS)*
3.3.7.3	*Cabling / Wiring*
3.3.7.3.1	*Cable Installation*
3.3.7.3.2	*Wire Harness*
3.3.7.4	*Racks & Supports*

	Design / Activities / Design & Engineering Objects
3.4	Support Engineering
3.4.0.1	*Operations Manual*
3.4.0.2	*Repair & Overhaul Manual*
3.4.0.3	*Remote Monitoring*
3.5	Recycle/ Disposal Engineering
3.5.0.1	*Recycle/ Disposal Manual*
3.6	Engineering Analysis
3.6.0.1	*Heat & Mass Balance*
3.6.0.2	*Computational Fluid Dynamics*
3.6.0.3	*Naval Architects*
3.6.0.4	*Structure Analysis*
3.6.0.5	*Thermal Analysis*
3.6.0.6	*Kinematics*
3.6.0.7	*State Transition Analysis*
3.6.0.8	*Logic Analysis*

Table 7 - Examples of Professional Disciplines

Professional Discipline	Example Professional Organisation
Aerospace engineering.	AIAA -- The American Institute of Aeronautics and Astronautics

May also be referred to as aeronautical engineering (or, when focused on applications beyond the earth's atmosphere, astronautical or space engineering). Concerns the design and development of aircraft, space vehicles, satellites, and missiles. Aerospace engineers also study the effects of flight conditions, principles that apply as well to travel through any fluid (air or liquid). Aerospace engineering combines elements of civil, electrical, mechanical, and metallurgical/materials engineering.

Agricultural engineering	American Society of Agricultural Engineers

The agricultural engineer may focus on soils and water (erosion, irrigation, waste water); design and construction of farm buildings; electrical power and distribution (for milk processing areas, for instance); food engineering (developing appropriate processing, storage, packaging, and handling systems); or power and machinery (the most common area of employment, involving the design or development of such equipment as tractors or livestock feeding systems.)

Automotive engineering.	Society of Automotive Engineers (SAE)

Design, development, testing, and assembly of land vehicles, not only cars but everything from earth-moving equipment to mass transit vehicles. Usually involving team effort of different types of engineers, automotive engineering requires expertise in civil, industrial, and mechanical engineering areas.

Bioengineering and Health Care Systems Engineering	The Biochemical Society The Biomedical Engineering Society (BMES)

Many differing specialities within this field combine biology, medicine, and engineering (particularly electronics). Bioengineering itself involves the study of biological systems (not necessarily human) applied for industrial, agricultural, environmental, or medical uses. Biochemical and genetic engineering are similar to bioengineering but more narrowly defined, involving applied study of structures and processes at the cellular level. Biomedical engineers research the life systems of humans, biomaterials, and other materials that may be compatible with human systems. They design such devices as pacemakers and artificial organs. Bioinstrumentation engineering or medical engineering involves design and development of equipment used in medical diagnosis and treatment. Clinical engineers work within health care systems or hospitals to design appropriate computer systems and other instrumentation. Rehabilitation/health care systems engineers work (often one-on-one) with disabled individuals, designing equipment to improve their lives.

Chemical engineering.	Institution of Chemical Engineers (IChemE) American Institute of Chemical Engineers Society of Chemical Engineers, Japan

Chemistry has to do with the composition and changes in composition of substances and with the preparation, separation, and analysis of substances. Chemical engineering is concerned with the manufacture on an industrial scale of substances from raw materials through controlled chemical and physical changes. Chemical engineering is closely allied, and overlaps considerably, with ceramic, petroleum, metallurgical, energy conversion, and sanitation engineering. In this discussion the emphasis will be on the work of those who call themselves "chemical engineers," the industries where chemical engineers find employment, and the processes whereby substances are manufactured efficiently and economically.

Civil engineering.	Institution of Civil Engineers (ICE) The Royal Institute of British Architects American Society of Civil Engineers

Civil engineers work with fabricated and natural structures. They design and supervise the construction of bridges, highways, dams, building, airports, harbours, flood control systems and vast array of projects that affect the quality of life for millions of people world-wide. Civil engineers today are designing methods and facilities to cope with many of our planet's most serious problems. In the face of foul air; decaying cities; roadways, and bridges; clogged airports and highways; polluted streams, rivers and lakes, the civil engineer is being called on to design solutions that are workable and cost-effective.

Computer engineering.   The British Computer Society (BCS)

A broad discipline that incorporates the fields of computer science and electrical engineering. Computer engineering emphasises the design and development of computers and computer-related technology, including both hardware and software.

Electrical engineering.   The Institution of Electrical Engineers (IEE)
The Institute of Electrical and Electronics Engineers, Inc (IEEE)

Electrical engineering deals with electricity - man's most versatile servant. It is a broad field with two major stems - electrical and electronics engineering. Electrical engineering is concerned with electrons, magnetic fields and electric fields - all invisible phenomena. Electronics engineering is concerned with … (need definition of electronics engineering -- separate category?).

Environmental engineering.   American Academy of Environmental Engineers

A popular concentration within chemical, civil, and mechanical engineering programs that is now also offered as an interdisciplinary major. Environmental engineers work in such areas as pollution control, hazardous waste management, water supply protection, and noise abatement, solving problems relating to human interaction with the environment.

Food engineering.   The Institute of Food Science and Technology (IFST)

Engineers involved in this branch of chemical engineering may find means of sterilising food or develop food additives, among other projects.

Industrial engineering.   Institute of Industrial Engineers (Hong Kong) Ltd

Industrial engineers are the "productivity people" who must provide leadership and integrate technology. They include the human factor in finding workable, effective solutions to production problems while retaining high standards of quality. No challenge can be greater than improving productivity - the application of knowledge and skills to provide improved goods and services to enhance the quality of life, both on and off the job. This must be done without waste of physical and human resources while maintaining the environmental balance. To continue to satisfy the needs and desires of mankind, the rate of productivity improvement must be greater than the increases of cost. Failure to accomplish this can contribute to inflation, recession and world-wide unrest.

Information Engineering   The Institute of Information Scientists
IEEE Computer Society

The theory, practice, and application of computer and information processing technology. Knowledge Engineering involves using specialised tools and techniques to capture and automate the application of knowledge. Data Engineering involves locating, gathering, and organising information to improve decision making.

Manufacturing/Production engineering.   Society of Manufacturing Engineers

Similar to industrial engineering and generally requiring a good knowledge of mechanical engineering, this specialisation focuses on such aspects of the manufacturing process as production control, the design of specialised tools and equipment, automation, and packaging.

Materials Engineering.   The Minerals, Metals & Materials Society's Home Page

Inorganic solid matter falls into three general categories: metals, ceramics, and polymers (plus composite materials combining the categories). Materials engineers may study the extraction, processing, refining, combination, manufacture, or use of any of these substances. Metallurgical engineers focus on the metals. Their work most commonly involves determining how to extract a particular metal most economically and efficiently from the unwanted material that is mined with it. This can be a challenge—for example, mined copper ore is usually only about 1 percent copper. Polymer engineering is a popular career area; in fact, about 30 percent of all chemical engineers are employed in this subfield. Polymer engineering involves combining like molecules into larger, more complex molecules that can offer new properties (for example, plastics). Ceramics engineering involves study of the character, development methods, and applications of clay and silica materials processed at high temperatures. Superconductivity is one major area of research in ceramics engineering. The separation of 'Metallurgical Engineering', 'Ceramics Engineering' and 'Plastics and/or Polymer Chemical Engineering' is restrictive and is becoming outdated. Most university departments and professional bodies now relate to 'Materials Science' or 'Materials Engineering', e.g. The Institute of Materials http://www.materials.org.uk. and The Society of Materials Science, Japan http://zairyo.jsms.or.jp/indexe.htm

Mechanical engineering.   The Institution of Mechanical Engineers (IMechE)
Japan Society of Mechanical Engineers

Society needs mechanical engineers that have the broad outlook necessary to solve complex problems. Disposing of nuclear waste, developing earthquake-proof structures, space stations, and underwater structures, manufacturing optical fibres, and cooling the next generation of supercomputers are just a few. Mechanical engineers with social insight and economic expertise are in demand now and will be in the future. Mechanical engineers work with many other technical people to solve the complex problems that society faces. The designers will utilise analytical calculations, scientific theory, and experimental studies with different models and prototypes to verify the workability, safety, and reliability of the design.

Mining engineering.   The Australasian Institute of Mining and Metallurgy

The educational background of a mining engineer includes civil, mechanical, industrial, and electrical engineering as well as a good grasp of geology. The mining engineer is involved throughout the mining process: planning and installing the mine; putting in access roads as well as power, drainage, and ventilation systems; building living quarters and community facilities for the miners and their families if needed; arranging for pollution control and safety; and restoring and rebeautifying the land after mining.

Marine engineering, naval   The Society of Naval Architects and Marine Engineers
architecture, and ocean engineering.   Society of Naval Architects of Japan (SNAJ)

These terms may be used interchangeably and curricula differ from program to program. Strictly speaking, naval architecture refers to the overall design and development of ships or other marine vehicles and structures. Marine engineering refers to the design and installation of electrical or mechanical equipment for ships and other marine facilities. Ocean engineering focuses on exploration and use of the ocean, generally either constructing structures in the ocean or locating and retrieving petroleum resources from the ocean floor.

Nuclear engineering.   Home page European Nuclear Society (ENS)

This specialisation involves the study of nuclear fuel cycles, which most commonly is applied in monitoring fuel and reactor safety in nuclear power facilities and developing ways to dispose of nuclear waste. Nuclear engineers may also develop and design nuclear power facilities and equipment or be involved with other nuclear applications such as in food sterilisation or space exploration.

Petroleum engineering.   SPE Society of Petroleum Engineers - German Section

The petroleum engineer is involved throughout the oil and gas extraction process, from the drilling of exploratory wells to the determination of the safest and most economical methods for petroleum recovery.

Road and Railway Engineering   Institute of Road and Railway Engineering

Geometrical design of roads, streets, motorways, intersections and interchanges; capacity of roads and intersections; traffic management and control in urban areas; road traffic safety; impact of roads and traffic including traffic noise on the environment; road materials technology; pavement design; optimisation of bituminous mixture properties; application of geosynthetics to pavement structures; pavements in historical and housing areas; methodology of transportation system planning; planning and design of road and public transport networks; forecasting of traffic volume; traffic processes, control and operation assessment of urban public transport; transportation problems in historical cities; mechanics of rail track structure, including track and rubble bed; modification of railway track construction, fasteners and junctions; track laying and maintenance operations and modernisation of railways; effective use of rail infra-structure for non-conventional and intermodal railway vehicles.

Safety engineering.   The Institute of Safety in Technology and Research (ISTR)

Safety engineers identify workplace hazards, design ways to control them and prevent injuries, and train employees. They are employed widely, but especially in manufacturing, mining, petroleum, and chemical industries. Two recent concerns for safety engineers have been product safety and robotics.

Systems Engineering   The International Council on Systems Engineering

Systems Engineering is an interdisciplinary approach and means to enable the realisation of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem:

- Operations; Performance; Test; Manufacturing; Cost & Schedule; Training & Support; Disposal

Systems Engineering integrates all the disciplines and speciality groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.

Textile engineering.   The Textile Institute

Involves study of the properties of fibres (natural and artificial) and their uses in developing products as well as the design and control of textile industry equipment.

Transportation engineering.   The Institute of Road Transport Engineers

Focuses on design and construction of ground systems of transportation. Programs also sometimes include study of the design of vehicles. The highway engineer plans details from location, to cost and usage estimates, to the structural design of the roads being built. The traffic engineer studies traffic flows and develops traffic control measures, for example computerised traffic signals.

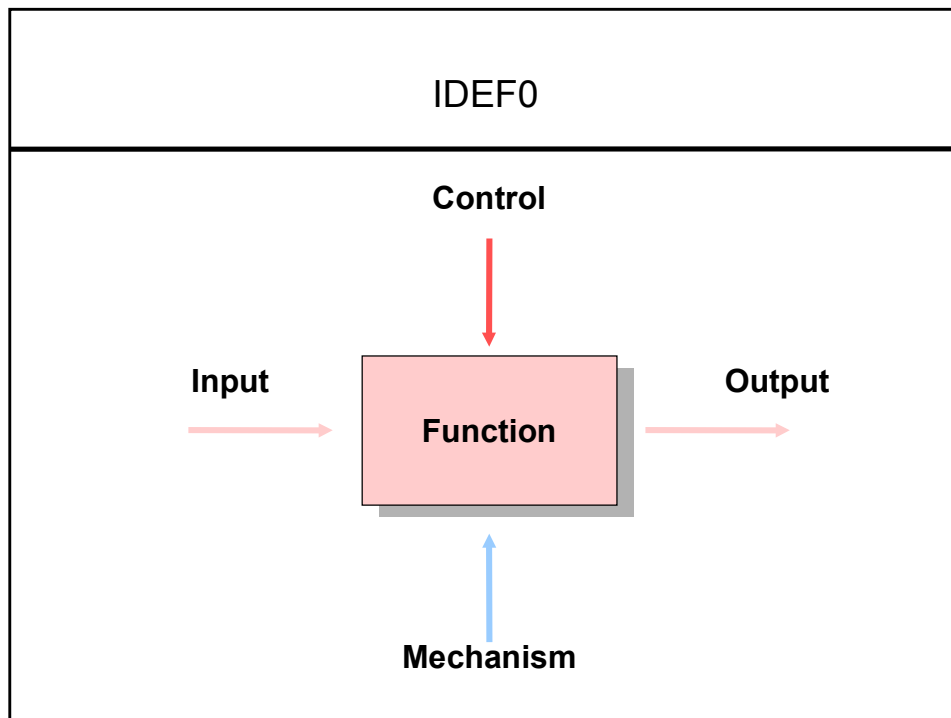# 12 Annex C - IDEF0 - Process Modelling

Figure 58 - IDEF0 Notation

IDEF0 is a method for modelling activities, processes and transformations. The diagrams consist of rectangles and arrows. A rectangle represents a function, which is an activity, process, or transformation. The arrows represent flows of data or objects from a source to use. These arrows may be inputs, controls, outputs or mechanisms.

The function creates one or more outputs and requires at least one control (constraint). Zero or more inputs may contribute to the function and zero or more mechanisms (means) may be necessary.

```
Note that IDEF0 models: —
```

- may represent functions that are **not always** activated , only functions that are applicable are activated

- do not show or imply **any time or order** of activation of the functions

Further information on IDEF0 can be obtained from reference 1, see Bibliography, page 97.

13 Annex D - Usage Scenarios and ISO 10303

13.1 Data Exchange and ISO 10303

In a modern computing environment, data exchange is commonly understood to be the exchange of neutral format data files between computer systems. A sending system translates data from its internal format and encodes it into an established neutral format. This file is then transferred to the receiving system where the data is translated into the internal format of the receiving system.

The architectural components that comprise a data exchange implementation include: -

- a sending system translator (pre-processor) to generate neutral data file

- a transport mechanism for sending neutral files to the receiving system

- a receiving system translator (post-processor) to convert neutral data files to an internal format

There are many well understood transport mechanisms available for distributing a data file, including electronic mail and File Transfer Protocol (FTP).

In the banking analogy, the bank statement, including both the data and the data context, represents the neutral data file. In traditional computer-based data exchange, the neutral data file usually contains only the data, not the context. The context of the data, or how the data values relate to meaningful concepts, is often defined *implicitly* by the data's location in the format file. Both the sending and receiving systems depend on *a priori* knowledge of the file format and its relationship to the data context. If this were true in the banking analogy, the account statement would contain only numbers; the bank and the customer would need to agree beforehand which numbers correspond to which account categories (i.e. line 1 would contain the balance, line 2 would contain disbursals during the reporting period, etc.)

ISO 10303 supports data exchange through the STEP physical file format. Each STEP application protocol provides a model which serves as an explicit standardised data specification for an established application context. It is this model that provides a documented explanation of the context (scope) and meaning (relationships) of the data to be exchanged. It is used, along with an encoding algorithm, to produce STEP physical files that contain both the data and its associated context, thus enabling effective and flexible communication between computing systems.

13.2 Data Sharing and ISO 10303

The successful development of a data sharing implementation requires that many different aspects of information technology be considered. Among those, controlled data access is a key element. Data access is the interface mechanism whereby a computer program can read or update the selected data in a data store. In the data sharing scenario, some portion of the database is intended to support joint usage and ownership. To successfully share data, the data access mechanism must allow multiple application systems to read, store, and manipulate the shared data.

Traditionally, data sharing systems are implemented as client-server systems or more recently as server-server (federated) systems. Therefore, multiple co-operating applications may have one or more data stores that are controlled by server functions. There may be data stored in these distributed data stores that are designated to be shared among many application systems. As in the banking analogy above, the communication protocols and implementation technologies required for data sharing implementations are more complicated than those of data exchange, and multiple data stores add to the complexity.

The information context for the shared data is embedded in each application's knowledge (the application logic), their physical schemas, and the steps required to access/update the shared data in the distributed data stores. Effective data sharing requires a mapping of these different data stores where shared data reside under a single data specification that is understood by the co-operating applications.

ISO TC184/SC4/WG10 N313
2000-09-01

ISO 10303 forms the basis for data sharing implementations via the AIM, conformance classes, and data instantiation rules and constraints that are specified in the mapping table. Collectively, these serve as the single data specification for the application systems that need to share data.

Because ISO 10303 is being developed as a communication standard, it is not intended to serve as an efficient and complete data structure for storage implementation. However, it can provide the necessary navigation paths for data access.

The design of a data sharing implementation must consider the system architecture and computing environments (e.g., hardware, software, and development tools) of all application systems that need to share data. The system design must address the unique interactions between the control structure and the component systems. The design strategy varies depending on the component systems, the computing environment, and performance considerations. These design strategies are not specified as and probably should not be a formal standard part of ISO 10303.

13.3 Data archive and ISO 10303

ISO 10303 is aimed at the exchange of product model data. Data Archiving is the exchange of data, not between partners but between the same organisation at different points in time. The challenge in developing an archiving system is defining strategies to cope with new systems and technologies that may evolve in the future. The use of a neutral format such as ISO 10303 to store archived data will be a key element and has a number of advantages.

- The format and structure of the data is well documented in the standard.

- The availability of systems to read the data should be better than for any proprietary format.

- The inclusion of the context of the data within the file will aid the identification of the correct data when it is retrieved from an archive.

- In the worst case, when an application is not available to read ISO 10303 data all is not lost. It will be possible to view the data (ASCII file) and to use the ISO10303 schema to understand the content. While this may not always be practical at least the access to the data is possible. This would not be true if the data was stored in a proprietary format.

A requirement of a neutral format archive system is the need to store the copies of the standard (ISO 10303 schema) as well as the data.

14 Bibliography

1. "IDEF0 (ICAM definition Language 0)", Federal Information Processing Standards Publication 183, Integration Definition for Function Modelling (IDEF0), FIPS PUB 183, National Institute of Standards and Technology, December 1993, http://www.idef.com/.

2. "A Proposed Integration Framework for STEP (Standard for the Exchange of Product Model Data)", NISTR 90-4295,April 1990, William F. Danner.

3. "GPDM - Generic Product Data Model", William E Danner, Yuhwei Yang, Version 0.9 Draft 5 Jan 91

4. "GEDM - Generic Enterprise Data Model", William E Danner, Yuhwei Yang, Version 0.2 Draft 5 Jan 91

5. "Generic Product-Data Model Resources for STEP", William E Danner, Yuhwei Yang, Nigel Shaw, Version 0.3 Draft 1 Feb 91

6. "STEP Framework, Concept and Principles"-Draft2-, March 22, 1991, James R. Kirkley, Brian K. Seitz

7. "Minutes of AP Development and Framework Meeting", June 27-28, 1991, Mark E. Palmer

8. "ISO 10303: Part 13: Description methods: STEP architecture and development methodology", date and status unknown

9. "Issues and Recommendations for a STEP Application Protocol Framework", National PDES Testbed Report Series, NISTIR 4755, Jan.17 1992, Thomas R. Kramer, Mark E. Palmer, Allison Barnard Feeney.

10. "Application Protocol Modeling Framework for Maritime", ESPRIT III 6041 MARITIME Deliverable D2401, October 15, 1993, Thomas Koch, Werner de Bruijn

11. "STEP Application Protocol Implementation", October 1995, Yuhwei Yang

12. "Developing APs using architecture and methods of STEP: Fundamentals of the STEP Methodology", September 1996, William F. Danner

13. "AP Development Guidelines for Shipbuilding" Working Draft, January 21, 1996, Jochen Haenisch, Peter Lazo

14. "The nature of industrial data", ISO/TC184/SC4/WG10 N64, Draft 0.7, June 27, 1996

15. "AP215 Ship Arrangements Overview", for Toronto Meeting, October 1996, TENNECO; Newport News Shipbuilding

16. "The Product Model - CALS Technical Goal", Forsvarets Materielverk (FMV) CALS Office, 1996

17. "Industrial Framework Model", V0.92, 13 July 1998, Chris Vaughan

18. "Review of STEP/SC4 AP Framework Proposals and Related Recommendations Working Draft V0.8", 3 Aug. 1998, Chris Vaughan

19. "Product Life Cycle Support, Statement of Technical Requirements", John Dunford, November 1998

20. "Proposal for STEP/SC4 Standards Development Directives", 19 January 1999, WG10 Nxxx, H. Hiraoka, Y. Ishikawa

21. "SSDM: STEP/SC4 Data Modelling Framework related Issues and Recommendations, V0.9D", December 1999, WG10 N240, Yoshiaki Ishikawa, IHI

22. Overview description of STEP Modularization - to be published

15 Index